

# NASA Contractor Report 3922(33)

## USSR Space Life Sciences Digest

*Issue 28*

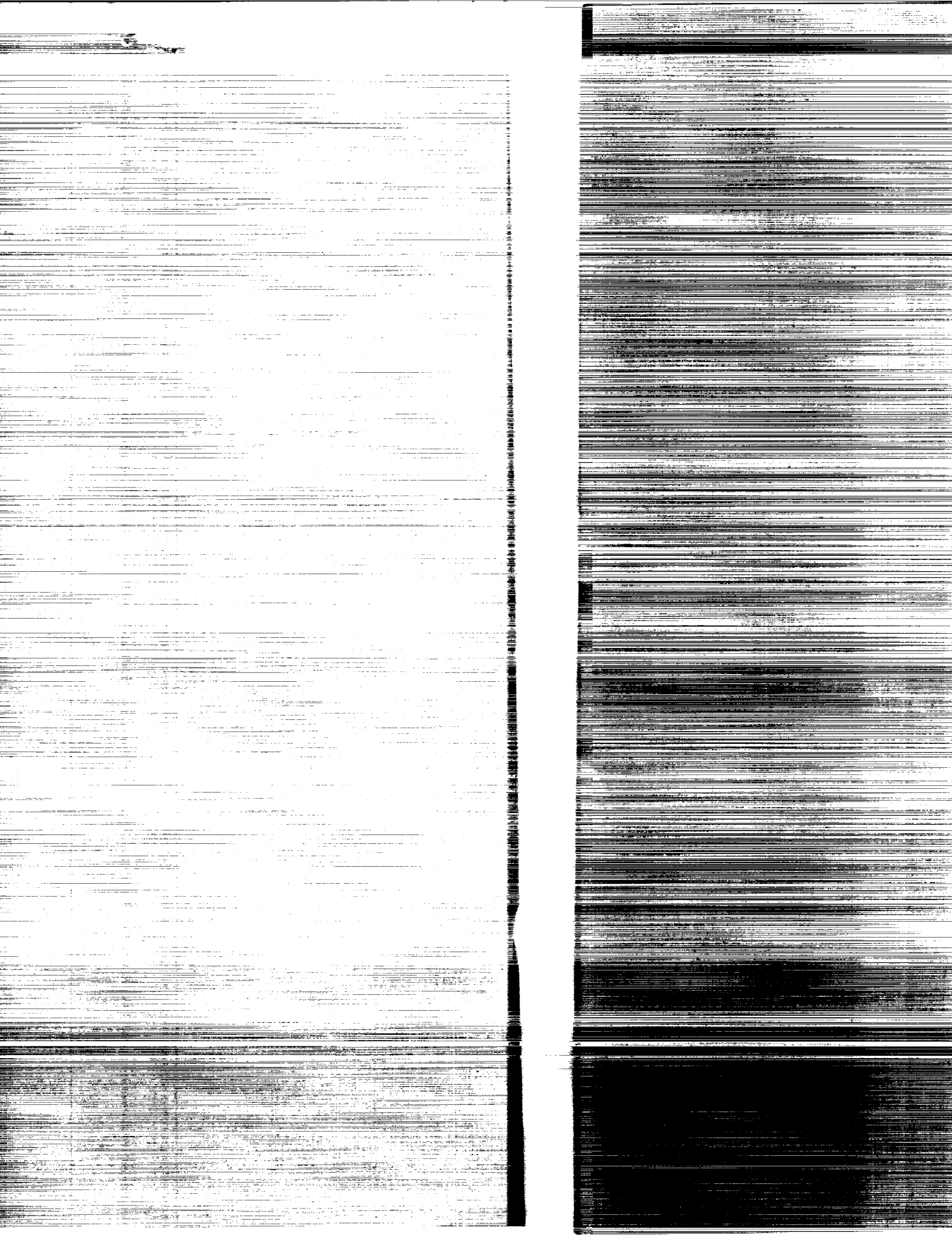
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NASA Contractor Report 3922(33)

# USSR Space Life Sciences Digest

*Issue 28*

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## USSR Space Life Sciences Digest: Issue 28 Reader Feedback Form

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract Number rendering	Incorrect or inappropriate term	Suggested
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**PLEASE RETURN TO: Dr. Lydia Stone**  
**Lockheed Engineering**  
**and Sciences Company**  
**600 Maryland Ave. SW**  
**Suite 600, East Wing**  
**Washington, DC 20024**



## FROM THE EDITORS

This is a special double issue of the Digest, covering material in issues 1 and 2 of the Soviet "Space Biology and Aerospace Medicine" [Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina] Journal for 1990. Issue 29, will also be a double issue, covering issues 3 and 4 of the same journal. In this issue the following abstracts present or discuss space flight data: Botany P1235, P1236, P1253, P1249; Cardiovascular and Respiratory Systems P1231; Musculoskeletal System P1286, P1287, P1288, P1289, P1290; Neurophysiology P1246; Radiobiology P1261, P1250; Space Medicine P1267. A special feature in the Developmental Biology section provides a translation of a popular article dealing with the hatching of quails on board Mir.

This Digest issue marks the first use of a panel of experts to review the technical terminology and consistency in Digest abstracts. We would like to thank the following scientists for their valuable contributions:

Dr. Gary Coulter  
Dr. Victoria Garshnek

Dr. Ronald Dutcher  
Dr. Russell Rayman

Dr. Mary Ann Frey  
Dr. John Uri

We also thank Mr. Glenn Ferraro for his help in producing the Digest.

Finally this Digest issue contains a reader survey. We hope that many of you will take the time to fill it out and return it to us at the address below. Results will be used to help us plan and improve future Digest Issues.

Address correspondence to:

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We periodically send out a survey to assess how well the Digest meets reader needs and in what ways it might change to improve its performance. Please take the time to fill out this survey and return it to: Dr. Lydia Razran Stone/Lockheed Engineering and Sciences Corporation/ 600 Maryland Avenue SW, Suite 600/Washington, DC 20024. Of course you need not answer all questions and you are encouraged to add comments of your own.

Name: \_\_\_\_\_

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Please rate the following characteristics of the Digest according to the rating scale below:

5 = excellent; 4 = good; 3 = fair; 2 = poor; 1 = very poor

Selection of material for relevance to space life sciences issues (     )

Presentation of relevant information from papers and other materials (     )

Technical terminology (     )

Overall readability (     )

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In the last year or two, the overall quality and utility of the Digest have:

- generally improved (    )
- generally decreased (    )
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- fluctuated erratically (    )
- other (    )
- unable to judge (    )

Please provide additional comments in the space below. We welcome your feedback!



## PAPERS:

P1239(28/90)\* Ivnitskiy YuYu, Moiseyev NYa.

*Tolerance of mice to various types of hypoxia and X-ray irradiation after exposure to hypoxia.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 32-33.

[21 references; 10 in English]

Tolerance, Hypoxia; Radiobiology, X-rays

Mice

Adaptation, Hypoxia

**Abstract:** This study investigated resistance to the effects of X-rays, high altitude, gas, anemic, tissue [histotoxic anoxia], and mixed hypoxia over a 2-day period after acute severe hypobaric hypoxia. Resistance of oxidative phosphorylation to uncoupling was also studied under these conditions. Subjects were 2880 male albino mice. The experimental animals were "raised" in a barochamber to an altitude sufficient to provoke convulsions in some subjects (9600-10200 m, rate of ascent 12 m/sec., rate of descent 100 m/sec) five times in a single session. Subsequent to this treatment, the barochamber was again used to simulate ascent to a height of 10,000 m (high altitude hypoxia) in one group of mice. In other groups, gas hypoxia was induced with an oxygen-nitrogen mixture ( $pO_2=42$  mm Hg), and anemic hypoxia by a carbon monoxide mixture. Hyperoxic hypoxia was created in an oxygen atmosphere at a pressure of  $6.10^5$  Pa. Resistance was computed as the ratio of proportion of animals surviving in the experimental group to that in a control group (no preliminary exposure to hypoxia). Histotoxic anoxia was induced with potassium cyanide and mixed hypoxia with sodium nitrite and potassium persulfate. Uncoupling of oxidative phosphorylation was induced with 2,4-dinitrophenol introduced intraperitoneally in a range of doses from minimal to lethal. X-ray irradiation utilized a range of doses from minimal to fatal at a dose rate of 0.67 Gy/min. Death rate was computed for a period of 30 days. The dose response curve for X-ray irradiation and intraperitoneal administration of substances was computed using a computer program. In these conditions, dose modification factor was used as the resistance parameter.

Previous exposure to hypoxia has three types of effect on resistance to the various factors. Acute hypobaric hypoxia increased resistance to high altitude and gas hypoxia 2 hours after first exposure. However, resistance normalized when the interval was 1 day. Resistance to carbon monoxide, potassium cyanide, and dinitrophenol was not affected at all by adaptation to hypoxia. A completely different pattern was observed when the mice were tested for resistance to sodium nitrite and potassium persulfate (which led to the formation of methemoglobin) and also to hyperbaric oxygen. Tolerance to these factors increased significantly 24 hours after the first hypoxic exposure. The same was true for resistance to X-rays.

The authors attribute the first type of response — short-term increased resistance to high altitude and gas hypoxia — to compensatory responses to initial hypoxia, such as increased pulmonary ventilation, rate of blood flow, and oxygen capacity of tissues and blood. These responses do not affect anemic and histotoxic hypoxia or uncoupling of oxidative phosphorylation because the compensatory responses fail to limit rate of ATP resynthesis in tissues. The factors to which hypoxia increased resistance after 24 hours — sodium nitrite, potassium persulfate, oxygen and X-rays — all have the capacity to generate or stimulate production of active free radicals. The authors therefore attribute the protective effects of preliminary hypoxia on resistance to these factors to activation of the antioxidant protection system of cells.

## ADAPTATION

Figure 1: Pattern of tolerance to hypoxic hypoxia, carbon monoxide, and hyperoxia after exposure to high altitude hypoxia in mice

Figure 2: Pattern of tolerance for sodium nitrite, potassium persulfate, potassium cyanide, and dinitrophenol after exposure to acute high altitude hypoxia in mice

Figure 3: Pattern of radio-resistance after exposure to high altitude hypoxia in mice

P1281(28/90)\*\* Shatemirova KK, Zelenshchikova VA, Min'ko YuV.

***Catalytic properties of monoamine oxidase in adaptation to barochamber hypoxia.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 54-56.

(15 references; 5 in English)

Enzymology, Monoamine Oxidase, Mitochondrial Membrane

Rats

Adaptation, Hypoxia

**Abstract:** The goal of this work was to study the catalytic properties of monoamine oxidase (MAO) fragments of the mitochondrial membrane in livers of rats exposed to hypoxia in a barochamber. Subjects were adult male Wistar rats divided into 4 groups. Group 4 was the control. The experimental rats were subjected to decreased atmospheric pressure corresponding to an altitude of 6500 m for 1 day (group 1), 5 days (group 2), and 21 days (group 3). Subjects entered the chamber at an altitude equivalent of 1500 m; altitude was increased by 100 m/day until the target altitude was reached. A control group did not undergo the barochamber procedure. After treatment was completed the rats were sacrificed, the liver removed immediately, washed with chilled saline and a 10% homogenate prepared in a 0.25 M solution of sucrose. Fragments of the mitochondrial membrane obtained through differential electrophoresis served as the MAO-containing material. Activity of the enzyme was estimated from liberation of ammonia during incubation of the fragments in an oxygen atmosphere at 37°C in samples containing 1.5-2 mg protein, a 0.1% phosphate buffer, and one of the following substrates in an optimal concentration: serotonin, tyramine, benzylamine, cadaverine, lysine, histamine, and GA BA. Duration of incubation ranged from 15 to 45 minutes as appropriate. After incubation, the samples were fixed, and the precipitates separated through centrifugation. Ammonia liberated by the monoaminoxidase reaction was measured in a protein-free filtrate by isothermic diffusion, followed by observation of response to Nessler's reagent. Level of lipid peroxidation was estimated in the same preparations of mitochondrial membranes on the basis of concentration of malonic dialdehyde (MDA). Quantity of protein was also assessed.

Exposure to hypoxia for 1 day had no effect on MAO activity. Exposure lasting 5 days decreased activity of MAO by 17, 18, and 19% when benzylamine, tyramine, and serotonin were used as substrates, while MAO activity increased in rats receiving 21 days of barochamber training by 91, 33, and 32% using the same substrates as above. Concentration of MDA in mitochondrial membrane fragments of the liver increased by 31, 64, and 41%, for hypoxia exposure of 1, 5, and 21 days, respectively. Liver MAO of rats exposed to hypoxia revealed a capacity to deaminate lysine, histamine, cadaverine, and GABA, which is not the case with the normal enzyme. Evidently the stimulation of lipid peroxidation of polysaturated fatty acids in the mitochondrial membrane resulting from hypoxia exposure changes the substrate specificity of MAO, and thus the catalytic properties of the enzyme. This new capacity can meet the need for additional mechanisms for detoxification of amines. These changes in MAO can be considered a natural mechanism of adaptation.

Inhibitor analysis showed that only type A MAO is responsible for the modification of the catalytic activity of the enzyme.

## ADAPTATION

Table: Deamination of nitrogenous compounds by fragments of mitochondrial membranes of the liver of Wistar rats exposed to hypoxia in a barochamber for varying durations

Substrate	Control	Hypoxia duration, days		
		1	5	21
Benzylamine	265	278.5	219.9*	507.0*
Tyramine	1004	1021.6	821.7*	1330.5*
Serotonin	390	439.9	315.9*	517.5*
Lysine	0	38.0	56.8	50.0
Histamine	0	35.9	50.2	48.4
Cadaverine	0	37.9	46.0	54.2
GABA	0	33.0	45.0	54.2

Figure: Activity of MAO in fragments of the mitochondrial membrane of the livers of rats as a function of concentration of substrate (serotonin) for control animals and animals exposed to hypoxia for 1, 5, or 21 days



### CONFERENCE REVIEW:

CR14(28/90)\* Gippenreyter YeB.

Report on: *International Conferences on Mountain (High Altitude) Medicine*, Prague, Czechoslovakia, October 19-23, 1988.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 57-59.

**Key Words:** Adaptation, High Altitude, Hypoxia, Personnel Selection, Human Performance

Excerpts: In recent years, the number of studies of human response to high altitude conditions has increased substantially. This can be explained by the expansion of human activity in mountain locations: building of new industrial concerns, sports and recreational facilities, scientific research institutions, health resorts and treatment centers, and also the development of sciences associated with aviation and space medicine. In addition to constant exposure to hypoxia due to residence at high altitude, humans may periodically experience the effects of oxygen insufficiency and other aspects of the climate at high altitudes if they participate in certain types of occupational or athletic activities. The support of normal vital activity and human performance under such conditions is one of the major problems of environmental physiology. The suitability of the use of response to acute hypoxia as a criterion in medical selection of individuals for jobs in aviation and cosmonautics is no longer open to question.

At the present time we have accumulated extensive data obtained at high altitudes and under laboratory conditions concerning human reactions to high altitude hypoxia. However, many aspects of the mechanisms underlying adaptation to hypoxia are still unclear.

These considerations lend particular significance to the topics discussed at the International Conference on High Altitude Medicine in Prague: results of study of human physiology and functional at high altitude locations; techniques used for assessing and predicting endurance of oxygen insufficiency in apparently healthy individuals; means for preventing accidents and injuries in the mountains; and provision of medical care under high altitude conditions.

The conference was organized by the Czechoslovak Association of Mountaineers of the Union of Physical Culture of Czechoslovakia at the request and under the aegis of the Medical Commission of the International Union of Mountain Climbing Associations. Its sponsors were the Czechoslovak Society of Sports Medicine, the Jan Purkinje Society of Medical Associations of Czechoslovakia, and seven Czechoslovak mountain-climbing clubs.

Participants in the conference were 145 specialists from 23 nations, including Austria, Belgium, Great Britain, Hungary, GDR, Greece, Denmark, Spain, Italy, the Netherlands, Norway, Bulgaria, Poland, the USSR, France, FRG, Czechoslovakia, Switzerland, Sweden, and Yugoslavia.

Ten Soviet scientists attended the conference, representing the Institute of Biomedical Problems of the USSR Ministry of Health (Moscow), the A.A. Bogomolov Institute of Physiological Problems (Kiev), the Institute of Physiology and Experimental Pathology of High Altitudes of the Kirghiz Academy of Sciences (Frunze), the Elbrus Biomedical Station of the Ukrainian Academy of Science (Terskol), the Lvov Medical Institute and Scientific Research Institute of Hematology and Blood Transfusion (Lvov), the Institute of Medical Genetics of the USSR Academy of Medicine (Moscow), the Moscow Psychiatric Scientific Research Institute of the Russian Ministry of Health, and also practicing physicians working at the International Mountain Camps of the USSR State Commission of Sports and sports training bases.

## ADAPTATION

Specialists from 12 European nations presented 38 papers and 15 poster sessions. These presentations cited results of scientific research under the extreme conditions of high altitude and contained information of a practical nature, mainly dealing with the following problems:

- evaluation of human endurance at altitudes at maximum tolerance limits and testing of physiological functions under simulated and actual high altitudes;
- accidents, injuries, and incidence of disease during mountaineering and recreational rock-climbing, their prevention and treatment;
- psychological support of mountain climbing;
- instruction and training of mountain and rock climbers from a medical standpoint.

Ye.B. Gippenreyter (Moscow) spoke on "An expert evaluation of endurance of high altitude in candidates for participation in the Soviet 'Everest-82' expedition" (co-authors O.G. Gizenko and V.B. Malkin), commented on the Soviet popular scientific films "Himalayan Camps" and "Assault on Everest," and presented the organizers of the conference with a monograph, "Human Physiology Under High Altitude Conditions," written by scientists of the Institute of Biomedical Problems of the USSR Ministry of Health.

Other Soviet participants discussed the characteristics of thermal regulation in the mountains (P.V. Beloshitskiy, Terskol), the mechanisms underlying individual differences in tolerance of hypoxia (O.H. Krasnyuk, Kiev), change in physiological function during shift work at an altitude of 1750 m (A.A. Maksimov, Frunze), the role of the thrombin-plasmin system in adaptation (I.I. Birka, Lvov), psychological changes in trained mountaineers at high altitudes (T.A. Volkova, Novomoskovsk), psychophysiological training of mountaineers (M.A. Mikhaylov, Moscow), and presented a case study in the treatment of high altitude acute brain edema in a Japanese climber on Mount Communism, in the Pamir range (S.G. Pryanikov, Alma-Ata).

Among the foreign research studies reported at the conference, the most interesting from our point of view were the reports on the study of the process of high altitude acclimation and the performance dynamics of high altitude mountain climbers (J.-P. Richalet, et al., France) and on the prognostic testing of physiological functions in candidates for the 1984 Everest expedition (L. Hubacova, et al., Czechoslovakia).

The French specialists evaluated performance on the basis of maximum altitude attained in climbing the Himalayas. Observations were made of 174 climbers (136 men and 38 women). Before the expedition they were tested for level of  $\text{VO}_2 \text{ max}$  and the response of the cardiovascular system to breathing of a hypoxic atmosphere equivalent in oxygen level to an altitude of 4800 m, while they exercised on a bicycle ergometer to 50%  $\text{VO}_2 \text{ max}$ .

For comparison, it may be noted that an analogous method was used for selecting members of the Soviet Everest-82 expedition. This method, proposed by V.B. Malkin, utilized a provocative test combining the effects of hypoxia and exercise. The atmosphere used here contained 9.5-10% oxygen, simulating conditions of the future base camp of the expedition at 5300-5400 m, i.e., 500 m higher than that used for the French experiment. The French established that the maximum altitude attained was a function of  $\text{VO}_2 \text{ max}$  but not of heart or respiration rate during the combined tests (hypoxia plus exercise) before the expedition. Rate of development of acute high altitude sickness, on the other hand, was associated with the two latter parameters, but did not depend on  $\text{VO}_2 \text{ max}$ . High altitude sickness was observed most frequently in individuals younger than 18 and older than 50. Acclimation to high altitude conditions and thus performance dynamics, in their opinion, proceeds in four phases: phase 1 — hours 0-6; phase 2 — 6 hours - 1 week; phase 3 — weeks 1-3; phase 4 — more than 3 weeks. In phase 1, symptoms of acute high altitude sickness are absent or minimal. In phase 2 the symptoms reach their maximum, but are accompanied by the development of acclimational shifts, with heart and respiration rate

## ADAPTATION

being critical. In phase 3 maximal performance is attained, with the determining role played by  $\text{VO}_2$  max. During phase 4 performance and general state gradually begin to decline.

The Czechoslovak scientists studied 13 individuals — 8 candidate members of the Everest expedition and 5 scientists. They evaluated endurance using ascent in a barochamber to a height of 7000 m at rest or while performing physical exercise on a bicycle ergometer with a number of physiological, psychological, and biochemical parameters recorded. The results obtained formed the basis for selecting personnel for the Everest expedition.

## PAPERS:

P1252(28/90)\* Vlasov VV, Kopanev VI.

*The effects of working in aviation on health status (epidemiological data).*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 4-9.

[56 references; 43 in English]

Aviation Medicine, Health Status

Humans, Aviation Personnel

Aviation Professions

**Abstract:** This review article considers the most reliable epidemiological data relevant to the assessment of how working in aviation affects the health status of personnel — results of studies of life-span and prevalence of various diseases. U.S. studies on cause of death have shown that, for their ages, flight personnel have lower death rates. The single longitudinal study performed confirmed this result. There are two hypotheses as to why this should be the case. The first is that the selection process leads to only healthier individuals entering this profession. The second invokes the high quality social and medical support, healthy lifestyle and other long-term factors. The majority of researchers favor the first hypothesis. Data about incidence of disease in flight crews may be somewhat distorted by over-zealous diagnosis of incipient ischemic heart disease. U.S. data indicate higher rates of injury and disease for aviation personnel than analogous workers, but these data are likely to indicate greater vigilance on the part of aviation physicians. Ischemic heart disease is the leading cause of death and disqualification for flight personnel in all countries. Incidence of myocardial infarction appears similar in flight personnel and the general population. Although ischemic heart disease is reported less frequently in the former, this may be due to selection and higher "complaint" threshold. Where signs of essential hypertension disqualify personnel for flight work, incidence of this disease is diminished in air crews. Cancerous tumors are equally common in flight crews and the general population. Data on comparative incidence of neurological and psychological disease in flight crews are not reliable. Such conditions are used to disqualify candidates in flight school. Incidence of glaucoma appears lower in aviation personnel than the population in general, possibly due to stringent vision requirements. Although flight crews frequently complain of backaches, they are hospitalized less frequently than the norm for back complaints. Gastrointestinal disease is less frequent than normal in flight crews. Health status of cosmonauts is even better than that of flight crews. Data are summarized as indicating that flight crews are in better health than the general population. However, these data do not provide reliable bases for drawing conclusions about the effect of aviation occupations on health.

Figure 1: Overall death rate in a group of 1000 aviators aged 23-60 and a corresponding population cohort in the USA

Figure 2: Frequency of ischemic heart disease and myocardial infarction in civil aircraft pilots in the U.S. and in the population in various age groups

Figure 3: Frequency of atherosclerotic damage to the coronary arteries in flight personnel of various ages

P1271(28/90)\*\*Demirchoglan GG, Konakhevich YuG, Petlyuk VKh, Peshkov RV, Khlomenok PN, Sholpo LN, Brazhnik VI.

***Experimental evaluation of the displacement of center of mass of the body in a man-chair system when the head is nodded.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 24-25; 1990.

[1 references; none in English]

Biomechanics, Displacement of Center of Mass, Head Nodding

Humans

Aviation Medicine, Ejection Seat

**Abstract:** This paper describes an experimental investigation of the displacement of body center of gravity when the head is nodded while a subject is sitting in an ejection seat under static conditions. A special experimental set-up was used, including a full-scale mock-up of an ejection seat on a dynamographic platform with an oscillograph. A special sensor recorded head displacement. A total of 669 men were examined and 55 selected on the basis of anthropometric characteristics (body weight, standing and sitting height, and other measurements) so that these accorded with the average in flight personnel. The experiment was conducted in four stages. In the first stage the subject donned a helmet with a microphone, was strapped in the seat with a harness, and assumed the initial posture (legs outstretched, arms on the arms of the seat, head pressed against the headrest). When the head was displaced by nodding, the displacement of body mass within the man-chair system was recorded. At subsequent stages the shoulder restraints were progressively loosened by 30, 60, and 90 mm to allow nodding. A total of 220 trials was conducted with each individual participating in 5 trials. A graph was constructed showing displacement of center of body mass in the man-chair system as a function of displacement of the head forward with increasing slack of shoulder straps.

Table: Results of correlation-regression analysis

Figure 1: Diagram of the experimental set-up

Figure 2: Displacement of the center of body mass in a man-chair system as a function of displacement of the head when shoulder restraints were slackened by 0, 3, 6, and 9 cm

### PAPERS:

P1270(28/90)\*\* Nikolayevskiy YeYe.

*Diurnal rhythm of lipids, carbohydrates, and certain hormones in blood plasma in healthy pilots.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 21-23; 1990.

[22 references; 6 in English]

Metabolism, Lipids, Carbohydrates; Endocrinology

Aviation Medicine, Humans, Pilots

Biological Rhythms, Diurnal Rhythms

**Abstract:** The goal of this work was to study circadian characteristics of lipids, carbohydrates, and certain hormones in blood plasma of healthy pilots so as to generate the biochemical portion of a biorhythmic portrait of the healthy pilot. Subjects in this clinical biochemical study were 30 healthy pilots, aged 30-39, and 15 healthy individuals not working in aviation. Studies were performed during 2 weeks of the summer. All subjects came from the same geographical area and consumed a similar diet during the study. Over the course of a day concentrations of cholesterol, triglycerides, total lipids, and  $\beta$ -lipoproteins were measured in blood plasma using a standard kit. Glucose levels and hydrocortisone, aldosterone, testosterone, and estradiol were also measured. The data were processed on a computer, using the kosinor? algorithm. Constructs utilized in this algorithm are the mean daily value of parameters, amplitude of the rhythm, and the acrophase — the mean time of the diurnal maximum.

In pilots the mean daily values of lipids and hormone concentrations are elevated relative to those of the general population. This is especially true for cholesterol, the daily peak for which was 129.4% of control values in the pilots. Mean value of blood sugar was lower for flight personnel. Amplitudes of diurnal rhythm of cholesterol, triglycerides, total lipids,  $\beta$ -lipoproteins, hydrocortisone, testosterone, and aldosterone were elevated in pilots. No difference was observed in amplitude of estradiol fluctuation, and amplitude of blood sugar fluctuation was lower in pilots. Time of day that peak amplitude occurred was similar to normal for triglycerides, testosterone, and estradiol. Peak times of other parameters were displaced significantly. Cholesterol peaked during the day for pilots and in the evening for nonpilots. Peak aldosterone for pilots occurred later and peak sugar earlier in the pilots. The authors consider study of circadian rhythms in pilots a promising technique for investigating occupational adaptation in such subjects.

Table: Circadian characteristics of lipids, hormones, and carbohydrates in healthy pilots and ground personnel

## PAPERS:

P1235 (28/90)\* Anikeyeva ID.

*Genetic studies of Arabidopsis seeds on space flights.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 22-25.

[14 references; 4 in English]

Genetics, Damage, Mutations, Accelerated Aging

Botany, *Arabidopsis*, Seeds

Space Flight, Short-Term, Long-Term; Zond-8, Soyuz, COSMOS, Salyut; Radiobiology, Cosmic Radiation

**Abstract:** The first experiment with *Arabidopsis* in space was performed on the unmanned Zond-8 station. Subsequent experiments were conducted on Soyuz spacecraft, COSMOS satellites, and Soyuz-Salyut orbital stations. Duration of exposure of seeds varied from 5 to 1254 days in a total of 22 experiments. In flight the air-dried seeds, with rare exceptions, were housed in hermetically sealed containers. After return to Earth the seeds were grown under aseptic conditions with constant illumination. The plants were analyzed for development, including fruit-bearing. Frequency of recessive mutations was determined by analysis of embryos. It is traditionally considered that death of plants at various stages of development decreased fertility, and observable mutations are due primarily to genetic damage, although physiological damage cannot be ruled out. Death of the embryo in the seed before germination, and death at the cotyledon and rosette stages are due to mass damage of cells of the root and apical meristem through major chromosomal aberrations. Death of the embryo before or during germination, which manifests itself as a decrease in seed germination ability, and also death of the seedlings during the cotyledon stage can be due to the factors being investigated or, partially, to certain adverse factors during the formation or maturing of the seeds. Death at the rosette stage may be completely due to the effect of space factors on the seeds, since the formation of rosette leaves begins only when the seeds germinate. Later death of plants and sterility of gametes are associated with induction of what are more minor aberrations, which can be retained during a number of cell divisions; the cells carrying them are apparently eliminated in meiosis. Recessive mutations are the result of microaberrations or point mutations. Thus, examination of these particular indices can provide a relatively complete picture of the reactions of the genetic apparatus of plants to space flight factors.

The most striking effect of space flight was on plant death. Space flight factors were only lethal when duration of exposure was longer than 400 days. Even for the shortest flights, survival was somewhat lower than for control groups, but this difference was not statistically significant. After 400 days plant survival dropped precipitously and after 827 days reached zero, while control plants survived at the baseline level. Space flight factors were lethal mainly during the early stage of development. Data on germinating ability of plants parallel the survival data.

When exposure was less than 400 days, survival at the cotyledon stage remained at a single level, no different than in control seeds. For longer exposures, death at the cotyledon stage increased sharply, reaching 100% at 827 days.

Because of the high death rate the effects of space flight factors on other parameters can only be studied with flight durations of less than 408 days. Death of plants after the cotyledon stage and also sterility of plants in both the control and flight conditions remained constant through the period and did not differ for the two groups. This same rate of sterility was retained in the control seeds up to 827 days.

Frequency of recessive mutations (pigment and embryonic lethals) in flight seeds exceeded the control by 1.5-2%, even for short-term experiments. This difference was not significant and remained constant up to 226 days. The increase in the number of mutations in the flight seeds was due mainly to embryonal deaths. Mutations in 408-day seeds were the same for the control and flight seeds.

To isolate the effects of individual space flight factors, simulation experiments were performed. It was demonstrated that the survival of plants grown from seeds exposed to vibration and acceleration similar to conditions during launch decreased from 70 to 46-48%. No effects were noted on fertility or frequency of recessive mutations. It is concluded that vibration and acceleration contribute substantially to the lethal effect of space flight factors. The authors previously speculated on the basis of a Salyut-6-Soyuz experiment that the sharp decrease in viability observed after 400 days in flight was due to premature aging of seeds in space. This hypothesis was confirmed in subsequent experiments, supporting the idea that aging occurs significantly sooner in space and proceeds more rapidly. Other authors have reported data on accelerated aging in space for *Crepis capillaris*, hamster cell cultures, and fruit flies. Results indicating slowed cell repair in mammals also have suggested accelerated aging, probably due to  $\gamma$ -radiation.

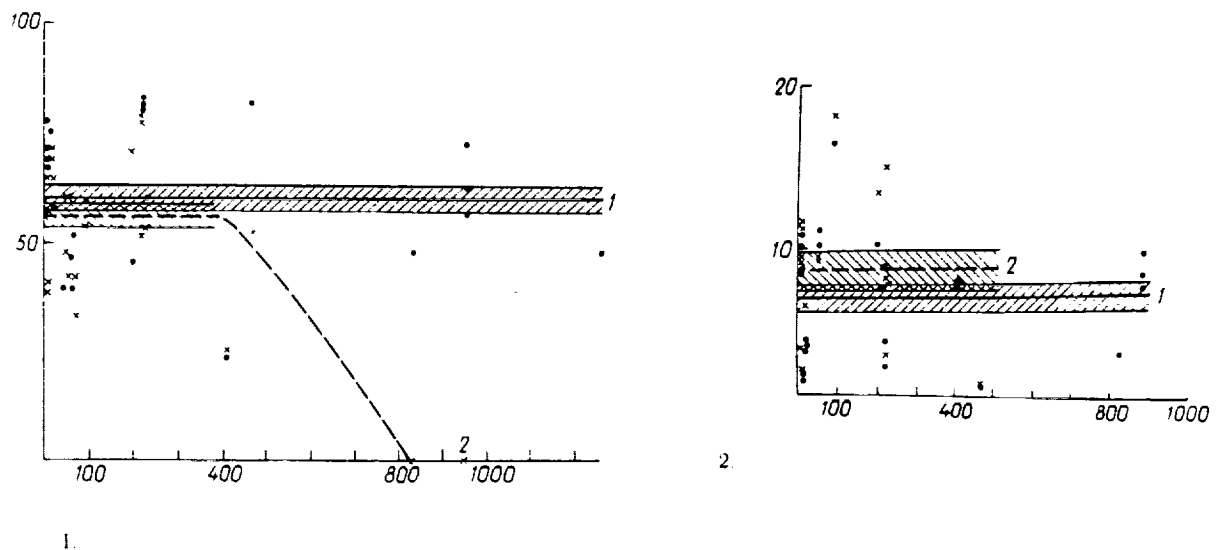


Figure 1: Survival of plants after exposure of seeds to space flights of varying duration

Here and in Figure 3: abscissa — duration of flight (in days); ordinate — number of plants surviving (in %) 1, dots — control 2, crosses — flight. Hatched areas are confidence intervals.

Figure 2: Number of mutant plants grown from seeds exposed to space

Abscissa — duration of flight (in days); ordinate; number of mutants plants (in %).  
Legend, same as Figure 1



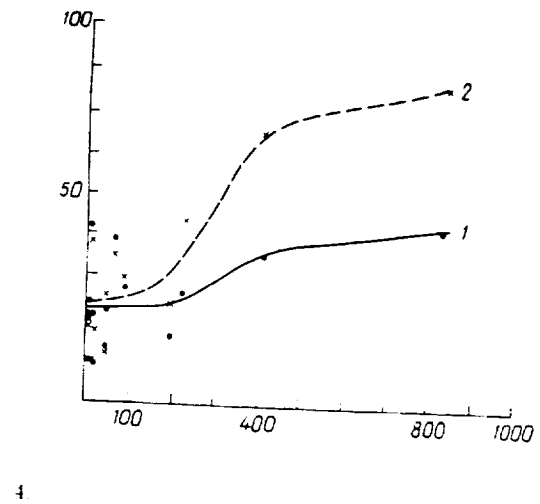
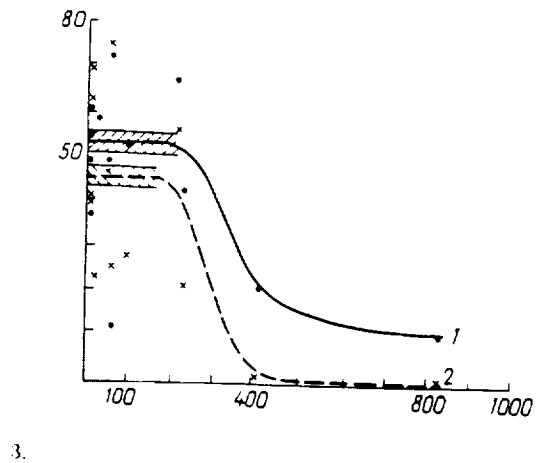


Figure 3: Survival of plants after exposure of  $\gamma$ -irradiated seeds to space  
1 — irradiated control; 2 — flight experiment

Figure 4: Death of plants in the cotyledon phase after exposure of  $\gamma$ -irradiated seeds to space

Abscissa — flight duration (days); ordinate — number of seeds that died

P1236(28/90)\*Nevzgodina LV, Maksimova YeN, Akatov YuA, Kaminskaya YeV, Marennyy AM.  
*The effect of the vacuum of space on seeds of lettuce (*Lactuca sativa*) exposed on COSMOS series biosatellites.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 25-28.

[10 references; 4 in English]

Genetics, Cytogenetic Effects

Botany, Lettuce Seeds

Space Flight, COSMOS-1129, -1514, -1760; Radiobiology, Cosmic Radiation, Solar Radiation

**Abstract:** This paper reports the results of research on seeds exposed directly to the space environment on the exterior of COSMOS-1129, 1514 and 1760. An attempt was made to distinguish between effects of ionizing cosmic radiation and solar radiation. Material consisted of air-dried seeds of *Lactuca sativa* (lettuce), with initial relative moisture of approximately 6%. The seeds were kept in a monolayer on 0.8-mm thick plates of cellulose nitrate and attached with a solution of polyvinyl alcohol. The plates also served as track detectors of multicharged ions of ionizing cosmic radiation. Approximately 50% of the seeds were shielded from solar radiation, while the remainder were exposed to direct sunlight. The shielding consisted of thin metal or metallic foil of thickness ranging from 0.0008 to 0.0035 g/cm<sup>2</sup>. It was hypothesized that the exposed and shielded seeds would differ only in their exposure to solar radiation, especially in the UV-range, since the foil was relatively transparent to ionizing radiation. To evaluate the dosage of absorbed radiation, the plates contained thermoluminescent detectors of approximately the same thickness as the seeds.

The plates containing the seeds and detectors were placed in special containers on the exterior of the satellites. Temperature sensors were placed near the seeds both above and below the foil shielding to determine maximal temperatures. During launch and descent the containers were covered with thermal insulation. During orbital flight they were directly exposed to space. After recovery the containers were transported to the laboratory for processing. The seeds were germinated and fixed and cytogenetic analyses performed. The radiobiological effects were estimated on the basis of yield of cells and with single and multiple chromosome aberrations in ana- and telophase of the first mitotic cycle. Detectors of absorbed dose and fluence of multicharged ions were processed using standard methods to determine integral values for ionizing cosmic radiation exposure.

Table 1 presents orbital parameters and radiation exposure data. In all three experiments, integral absorbed doses were approximately the same. The greater dose per day for the flight of COSMOS-1514 was attributable to the greater contribution of electrons emitted in polar regions of the satellite orbit, and also the lower thickness of the shielding foil. The fluence of multicharged ions was insignificant in all conditions, less than 1 particle per cm<sup>2</sup> per day. Table 2 presents the results of cytogenetic analysis of seeds exposed on the three flights. It should be noted that reliable differences were found between control and flight seeds on all three flights. More aberrations were found in flight seeds shielded by foil, compared to unshielded seeds. This difference was significant for the flights of COSMOS-1129 and -1760. When multiple aberrations were the dependent variable, differences between shielded and nonshielded seeds were significant in all three experiments. The authors ruled out the interaction of heavy particles with the foil itself and differences in temperature as being responsible for these differences in chromosome aberrations. They suggest that the apparent protective effect of UV-radiation may be due to photoreactivity.

Table 1: Conditions of experiments on lettuce seeds exposed directly to the space environment

Satellite	Orbital parameter			Flight	Foil	Absorbed	Fluence of particles with	
	apogee	perigee	angle of	durat.,	width,	dose, Gy	$Z \geq 6$ (LET>20), keV/ $\mu$ m	
	km	km	incl.°	days	g/cm <sup>2</sup>		shielded	unshielded
COSMOS:								
-1129	406	226	62.8	19	0.0035	25	1.15	3.30
-1514	288	226	82.3	5	0.0008	20	0.90	1.40
-1760	421	218	70.0	14	0.0029	26	1.07	---

Table 2: Results of cytogenetic analysis of seeds exposed on the outside of biosatellites  
(\*indicates statistically significant differences)

Satellite	Condition	No. roots	total	Number of ana- and telophases with aberrations			
				No.	%	No.	%
COSMOS: -1129	Flight:						
	shield	31	2321	202	8.70±0.58	24	1.03±0.20
	no shield	45	3721	216	5.80±0.38*	15	0.40±1.10*
	Control:						
-1514	shield	28	2248	27	1.20±0.23	0	0
	no shield	53	3892	50	1.28±0.18	1	0.02±0.02
	Flight:						
	shield	26	2610	39	1.49±0.24	16	0.61±0.15
	no shield	28	1993	14	1.19±0.24	2	0.04±0.04*
	Control:						
-1760	shield	27	4795	16	0.33±0.08	1	0.02±0.02
	no shield	39	6112	11	0.18±0.05	1	0.02±0.02
	Flight:						
	shield	42	2661	1182	44.41±0.96	396	16.77±0.69
	no shield	37	2847	624	21.92±0.78*	171	6.01±0.44*
	Control:						
	shield	38	3396	54	1.59±0.21	4	0.12±0.06
	no shield	40	3065	31	1.01±0.18	3	0.10±0.06*

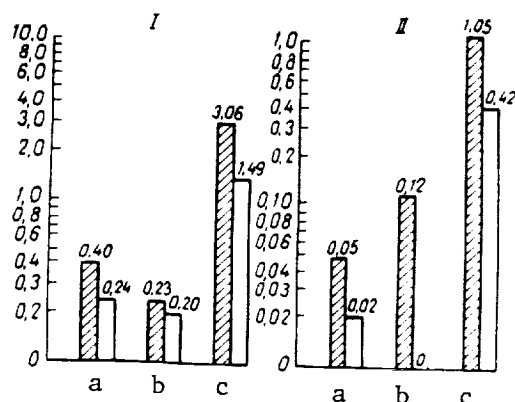


Figure: Number of aberrant cells per day of flight in lettuce seeds exposed directly to space on biosatellites (taking spontaneous mutation rate into account)

Abscissa: a - COSMOS-1129. b - COSMOS-1514; c - COSMOS-1760; Ordinate:  
I - % of aberrant cells; II - % of cells with multiple aberrations. White bars -  
without foil shielding; hatched bars - with foil shielding

P1253(28/90) Abramova VM, Vasil'yeva NG, Verigo VV, Marennyy AM, Portman AI.  
**Study of the biological effects of heavy charged particles of cosmic radiation on a population of higher plants — *Wolffia arrhiza*.**

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I *All-Union Radiobiology Congress*) Moscow 21-27 August, 1989. Paper Abstracts. Volume III Pushchino: USSR Academy of Sciences; 1989.

Pages 562-563.

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

Botany, Biological Effects

*Wolffia arrhiza*, Duckweed

Space Flight, COSMOS-1887, Radiobiology, HZE Particles

**Abstract:** Information concerning the biological effects of heavy charged particles can only be obtained from space flights, since particles with  $Z > 8$  and energy  $\sim 200 \text{ keV}/\mu\text{m}$  cannot be produced with accelerators on the ground. A new subject for study of the effects of space radiation — *Wolffia arrhiza* (L.) — was used on the flight of satellite COSMOS-887. The population of this extremely small ( $1 \text{ mm}^3$ ) aquatic plant of the duckweed family was stored in flight in monolayers on the surface of a damp substrate between rigidly affixed layers of track detectors. Postflight it was determined that 25 heavy charged particles had passed through individual plants. The *Wolffia* plants usually multiply by budding, and thus several of the plants were just about to yield daughter individuals when they were exposed to the radiation. This led to the death of 39 individuals within a period of several days, attesting to the highly lethal effects of heavy ionized particles on green plants  $1\text{-}2 \text{ mm}^3$  in size. With the exception of these individuals, it was possible to assess in the flight group the state of population homeostasis of *Wolffia* plants under exposure to the combined effects of particles with lower energy and charge and other, nonradiation space flight factors.

Statistical analysis of age balance was performed after the plants in the flight group that had not been "hit" by cosmic particles and plants in a synchronous control group had been grown in a stationary mode in a controlled climate chamber. Observations after 1 to 3 months showed that there was a significantly ( $p=0.05$ ) lower number of young and old individuals in the flight group, while the number of mature plants remained constant. By the end of month 3, the normal age distribution was restored. The reversible nature of the changes in age group-distribution attests to the stability of the population to the effects of space flight factors.

The homeostatic population of *Wolffia* maintains stability of functioning due to the fact that genetically it is a mixture of pure lines, i.e., it combines the qualities of high heterozygote cross-pollinated plants and high homozygote individuals within the limits of clones. At the same time, due to this property and the dispersion of age states, as the population grew the frequency of morphological anomalies increased. Nonlethal radiation effects on mature dividing individuals were noted in the meristem cells of the third postflight generation from exposed plants.

The following developmental anomalies were noted in the flight population: fasciation, nonseparation of adult individuals, tumors, giantism, and dwarfism. While such events were completely absent in the control population, in the flight material the frequency of anomalies varied from 4 to 12%. The authors concluded that these anomalies may be attributed to the radiation factor, since  $\gamma$ -irradiation during a preflight experiment revealed that mass formation of analogous radiomorphosis occurred soon after exposure. The dose equivalent for these events may correspond to doses less than 10 Gy, with a dose rate of 7 Gy/min. Evidently in flight local damage to meristematic cells of surviving individuals induces anomalies representative of abnormal distribution of growth hormone.

These facts indicate that as the duration of exposure of *Wolffia* populations to space increases, one should expect selective increase in polymorphism and physiological instability. In populations that reproduce vegetatively, in the absence of recombinations, the radiation factor may become the source of transformations of genetic homeostasis, i.e., lead to microevolutionary shifts.

P1249(28/98)\* Rumyantseva VB, Merzlyak MN, Mashinskiy AL, Nechitaylo GS.

***The effects of space flight factors on the pigment and lipid components of wheat plants.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 53-55.

[15 references; 7 in English]

Botany, Pigment, Lipid Components

Wheat

Space Flight, Mir

**Abstract:** The goal of this work was to study the lipid and pigment structure of wheat plants grown during space flight. Subjects were 19-day-old winter wheat plants grown in the Svetoblok-M device on Earth and on Mir in December 1987. During the experiment, temperature was maintained at 22°, humidity at 30%, and illumination at 20-30 W/m<sup>2</sup> of photosynthetically active radiation. Live plants returned to Earth were immediately frozen in liquid nitrogen and delivered to the laboratory. The above-ground portions of the plants were not thawed, but homogenized, and lipids and pigments extracted. Pigments (chlorophylls and carotenoids) were measured quantitatively using a spectrophotometer. Concentrations of individual carotenoids were measured using densitometric scanning after separation. The fatty acid composition of lipids in the plant extract was measured with gas-liquid chromatography. Indices of desaturation were obtained. Composition of individual lipids was analyzed using thin layer chromatography. Individual classes of lipids were isolated with specific reagents. Because of the limited amount of material in flight, analyses were performed on a single sample. Analyses on control plants were performed on 4-5 samples.

Results showed that exposure to space was associated with a decrease in concentration of chlorophylls a and b, with no change in their ratio. Concentration of carotenoids also decreased. The ratio of the sum of chlorophylls to the sum of carotenoids did not change. Thus the decrease in pigment level occurring on space flights, which could be due either to depression of biogenesis or accelerated destruction of the photosynthetic apparatus, does not distort the balance between chlorophylls and carotenoids.

Analysis of individual carotenoids showed significant alteration of ratios among these pigments. The level of  $\beta$ -carotene decreased by almost a factor of two in flight tissues. On the other hand, flight plants retained a rather high quantity of xanthophylls, especially dioxycarotenoids. Since carotenoids serve various protective functions, the loss of  $\beta$ -carotene may affect the stability of the membrane systems. The lipids characteristic of the photosynthetic apparatus of higher plants were synthesized in space. Densitometry revealed no significant shifts in the distribution of these lipids, but there was a significant decrease in fatty acids in flight plants. These decreases occurred in the major unsaturated fatty acids of the chloroplasts and were accompanied by significant decreases in the index of lipid desaturation. Similar changes were characteristic of lipid peroxidation. This was confirmed by detection of conjugate dienes, the intermediate products of lipid peroxidation of unsaturated fatty acids, during flight.

The authors conclude that the decrease in the total level of pigments, acyl-containing lipids, and polyunsaturated fatty acids, and the appearance of products of lipid peroxidation suggest activation of oxidative free radical processes in space. At the same time, it cannot be ruled out that the changes observed may be a consequence of repair processes occurring in the pigment apparatus of the plant as a response to destruction caused by lipid peroxidation.

## BOTANY

Table 1: Effects of space flight factors on the level of photosynthetic pigments (in mg per g dry mass)

Pigment	Control	Flight
Chlorophyll		
a	4.61±0.02	3.19
b	1.49±0.03	1.03
a+b	6.10±0.05	4.22
a/b	3.11±0.06	3.10
Total carotenoids	1.54±0.02	1.08
Chlor. a+b/total carot.	3.96±0.1	3.92

Note: Here and in Tables 2 and 3, value for control plants represents the average of 4-5 measurements with standard error of the mean

Table 2: Effects of space flight factors on the relative concentration of individual carotenoids (in mol%)

Conditions	β-Carotene	Lutein+ Zeaxanthin	Violaxanthin	Neoxanthin
Control	30.8±0.15	58.2±0.25	1.8±0.01	9.2±0.04
Flight	16.1	72.8	3.4	7.7

Table 3: The effect of space flight factors on the concentration of higher fatty acids in wheat plants (in mol%)

Fatty acid	Control	Flight
Palmitic	17.3±0.2	19.5
Hexadecyl	2.9±0.1	3.9
Stearic	2.5±0.1	3.6
Oleic	5.2±0.1	8.4
Linoleic	15.3±0.2	15.1
Linolenic	56.8±0.3	49.5
Index of desaturation	10.6	8.3
Sum of fatty acids, mg/g dry mass	31.4±1.0	19.2

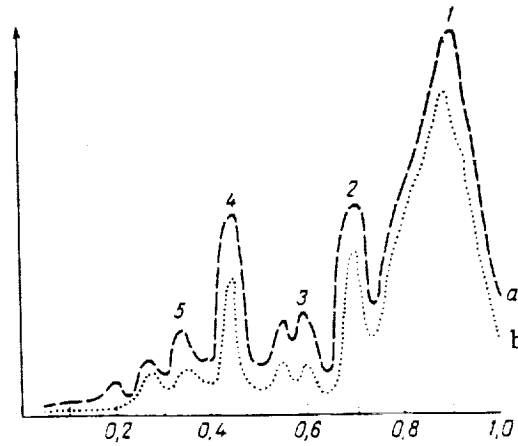


Figure: Densitogram of chromatogram of total lipids in wheat plants

1 — pigments, 2— monogalactosyl diacylglycerides, 3 — phosphatyl glycerides, 4 — digalactosylacyl glycerides. Abscissa —  $R_f$ ; ordinate - optical density (in units), a — control, b — flight



## MONOGRAPH:

M162(28/90) Grodzinskiy DM

Radiobiologiya Rasteniy, Радиобиология Растений [*Radiobiology of Plants*].

Kiev: Naukova Dumka; 1989.

[384 pages; 85 Figures; 7 Tables; 800 references]

Affiliation: N.G. Kholodnyy Botanical Institute, Ukrainian Academy of Sciences.

**KEY WORDS:** Botany, Radiobiology, Ionizing Radiation, Genetics, Mutagenesis, Cell Death

**Annotation:** This monograph presents for the first time an analysis of the general and specific plant responses to ionizing radiation at various hierarchical levels — from molecular to whole plant to phytocoenotic. The book discusses the characteristics of biochemical reactions to radiation, the cell-tissue syndrome, and the development of remote reactions to irradiation. The concept of “critical tissue” is introduced and criteria for quantitative assessment of radiation effects are considered. Mechanisms underlying the stimulation by radiation of the mutagenic effects of radiation sickness in various organisms are discussed from a comparative perspective, as are proliferative and interphase deaths of cells and multicellular organisms. This book is intended for radiobiologists, physiologists, and specialists in plant biophysics, and also may be useful to university instructors and students.

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## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

### PAPERS:

P1231(28/90)\* Gazenko OG, Shulzhenko YeV, Grigor'yev AI, Atkov OYu, Yegorov AD.  
*Medical investigations during an 8-month flight on Salyut-7-Soyuz-T.*  
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
24(1): 9-14.  
[16 references; 7 in English]

Cardiovascular and Respiratory Systems, Neurophysiology, Vestibular System, Perception,  
Sensory Systems, Body Fluids, Endocrinology, Metabolism, Nutrition  
Humans, Cosmonauts  
Space Flight, Long-Term, Salyut-7, Prophylactic Countermeasures, EVA

**Abstract:** This paper reports results of medical research on the 237-day flight of Salyut-7-Soyuz-T. Crewmembers were Commander L.D. Kizim, flight engineer V.A. Solov'yev, and physician O.Yu. Atkov. The general goals of the medical research program included further study of the acute period of adaptation to weightlessness and of mechanisms underlying changes in hemodynamics, metabolism, and other functions. Extensive use was made of electrocardiography and biochemical analysis techniques. In addition, the vestibular system and interactions among sensory systems were investigated.

Throughout the flight microclimate parameters were maintained at levels close to those on the Earth. Mean radiation dose rate never exceeded 10-15 mrad per day. Cosmonaut diet was based on the "menu-selection" system with a 6-day menu cycle. Rations contained 65% freeze-dried products and were balanced for all essential nutrients. A day's ration contained 142 g protein, 124 g fat, and 391 g carbohydrate, with 3150 total calories. Fluid consumption was not regulated and varied from 1.3 to 1.8 liter free liquid per man per day. Work-rest schedule was planned to include 8-9 hours of sleep, 8 hours 30 minutes of work, and 2 hours of exercise per day. Cosmonauts were allotted 2 days off per week. Frequently, however, this schedule was modified because of crewmembers' desire to complete various tasks. Prophylactic measures included physical exercise (on the bicycle ergometer and treadmill), using rubber "shock absorbers" and bungee cords and wearing loading suits, lower body, negative pressure, ingestion of fluid-salt supplements, and the use of anti-gravity suits immediately after landing and during the first few days of readaptation.

Throughout the flight the crewmembers rated their general state as good. The sensation of head fullness occurring on entry into weightlessness disappeared within 1-3 days. At times the cosmonauts complained of fatigue at the end of a work day, which however, was dissipated by a night's sleep. One cosmonaut lost 5 kg and the others maintained baseline body weight. Calf volume decreased by a mean of 14-19%, a figure that corresponded to data from previous long-term flights.

A device that could reproduce various types of visual stimuli on a television screen was developed for use in vestibular studies. During initial adaptation to weightlessness, spontaneous nystagmus or enhanced saccadic or drifting eye movements occurred at rest. Frequency and amplitude parameters of saccadic and drifting eye movements also changed. There was a decrease in thresholds for optokinetic nystagmus. Specific vestibular stimulation evoked altered compensatory eyeball movements and nystagmus, suggesting increased dynamic sensitivity.

In flight, resting heart rate decreased in one cosmonaut and increased insignificantly in the other two. Electrocardiography failed to reveal pathological changes in bioelectric myocardial activity in any cosmonaut. Blood pressure did not alter substantially, although there was a tendency for diastolic pressure to decrease in all three subjects. Echocardiography revealed

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

noticeable decreases in left ventricular end diastolic and systolic volume and in stroke volume in two cosmonauts and a decrease in left auricular diameter in one. The other cosmonaut displayed changes in the opposite direction: end diastolic, systolic volume, and stroke volume, and diameter of the left auricle all increased, while ejection fraction and heart rate increased. Cardiac output was virtually unaltered in all cosmonauts. No disruption of myocardial contractility was observed. On day 1 postflight, end systolic, diastolic, and stroke volumes were depressed, while ejection fraction increased in one subject.

Graded physical exercise on the bicycle ergometer adhered to the following schedule: baseline (2-3 minutes); stage 1 (800 kgm/min — 5 minutes); rest (1 minute); stage 2 (950-1040 kgm/min — 5 minutes); and recovery (5 minutes). During flight, mean heart rate at both stages of exercise was unchanged in one cosmonaut, and exceeded preflight levels somewhat in the other two, particularly in stage 2. These two subjects also required increased time for warm-up and recovery and ratio of heart rate to workload increased. As a rule, blood pressure values were lower than preflight. Echocardiography of two subjects showed decreased end systolic and diastolic volumes, stroke volume and cardiac output, and a slight increase in ejection fraction. End diastolic volume did not increase relative to resting value in flight. Exercising parameters of myocardial contractility exceeded preflight values, in spite of decreased stroke volume, suggesting that the myocardium was in good condition in both subjects.

The LBNP test was applied according to the following schedule: baseline — 3 minutes; -25 mm Hg — 3 minutes; -35 mm Hg — 5 minutes; -45 mm Hg — 5 minutes; recovery — 5 minutes. Heart rate during decompression was above preflight for two of the three cosmonauts, and this elevation was most pronounced (16-23% over preflight) at LBNP = -45 mm Hg. Changes in blood pressure were slight. Echocardiography of two cosmonauts in flight revealed individual differences in cardiac parameters. In one cosmonaut no changes occurred at -35 mm Hg, while at -45 mm Hg stroke volume and cardiac output exceeded preflight. In the other cosmonaut, the major echocardiographic parameters decreased compared to preflight levels. In both cosmonauts the ratio of filling of the left ventricle and stroke ejection was the same at rest and in response to LBNP, suggesting satisfactory myocardial contractility.

These reactions, which support a relatively high degree of central hemodynamic stability, are evidently triggered by fluid shifts. As a consequence of the shift of blood volume leading to increased central blood volume, low pressure mechanoreceptors in the cardiopulmonary region are stimulated, evidently inhibiting the vasomotor center, depressing adrenergic effects, and triggering a number of adaptive responses. First the receptors of the left auricle and ventricle respond by narrowing the pulmonary arteries, limiting influx of blood to the left heart. Then the receptors of the right heart respond by increasing pooling of blood in visceral organs and decreasing its circulating volume. This indirectly causes the kidneys to increase excretion of urine and electrolytes, leading to a partial fluid loss, which also tends to decrease circulating blood volume. These responses ultimately limit excess influx of blood to the heart and establish a new level of functioning of the circulatory system. Another relevant factor is the decreased effectiveness of the venous "pumps" and the decreased peripheral muscle pulsation pushing blood from the arteries through the capillaries to the veins. Changes in response to provocative tests are attributed to altered initial state of hemodynamics, and characterized by diminished circulating blood and interstitial fluid, increased blood volume in the cardiothoracic region, decreased vascular tonus, increased compliance and increased contractility of veins of the calf.

Fluid-electrolyte metabolism and hormonal status were studied in two cosmonauts using material from a 3-day urine collection, with fluid and food intake monitored and also venous blood taken from the veins during the same period of time (days 216-219 of flight). Both cosmonauts displayed decreased renal excretion of sodium, while one also retained fluid and potassium. Both cosmonauts displayed increased renal excretion of aldosterone and evidence for its increased synthesis, suggesting activation of the mineralocorticoid function of the adrenal

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

cortex. Renal excretion of ADH increased, while its blood level decreased. This contradicted other data from shorter long-term flights on which renal excretion of ADH decreased. This discrepancy may be due to decreased kidney sensitivity to ADH as flight duration becomes very long. Hydrocortisone increased in blood plasma, while concentration of deoxycortisone was virtually unchanged. Renal excretion of products of catecholamine metabolism decreased. These data, combined with previous flight data, suggest that weightlessness does not act as a continual stress-inducing stimulus.

During the flight of this crew, there were six EVAs with an interval of only 2 days between the last few. No changes were observed in the general state or performance of the cosmonauts during EVA, although they did display fatigue afterward. Changes in physiological parameters were close to those observed on previous training exercises in the underwater laboratory and thermal chamber, involving increased respiration and heart rate. During repeated EVAs it was noted that performance gradually improved and increases in heart rate and energy consumption diminished.

The most important result of the medical studies was that increase of flight duration to 8 months is not accompanied by development of qualitatively new functional shifts not previously observed on other, shorter long-term flights. The following effects were noted after the flight:

- decreased anthropometric parameters, perimeter of thigh and calf, and also weight loss (in two crewmembers);
- vestibular dysfunction (positional nystagmus, increased otolith reflex, optokinetic nystagmus, etc.);
- change in parameters of motor performance (disruption of the process of postural regulation, fine coordination, hypersensitivity to proprioceptive inputs, decreased speed-strength properties of muscle, etc.);
- symptoms of orthostatic and physical deconditioning;
- change in fluid-electrolyte metabolism and its regulation (decreased excretion of fluid and osmotically active substances; tonicization of hormonal systems regulating fluid-electrolyte homeostasis in the form of sharp increases in production and renal excretion of ADH and, to a lesser extent, aldosterone; increased concentration of calcium and its ionized fractions; decreased blood potassium; increased rate and amount of calcium excretion after calcium loading; change in regulatory functions of the endocrine system (increased hydrocortisone in blood and on day 8 of ACTH, increased renal excretion of hydrocortisone and deoxycortisone);
- activation of the sympathetic adrenal (with predominance of the hormonal component), choline- and histaminergic systems and decreased activity of the serotonergic system;
- development of the functional anemia syndrome;
- decreased immunological reactivity.

All these changes were reversible and gradually disappeared during readaptation.

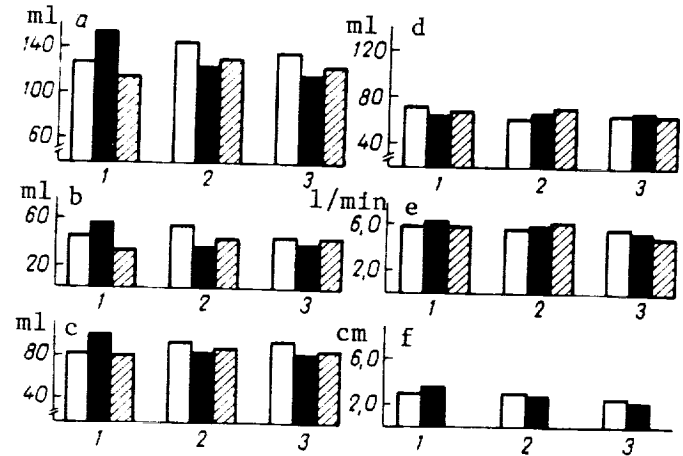
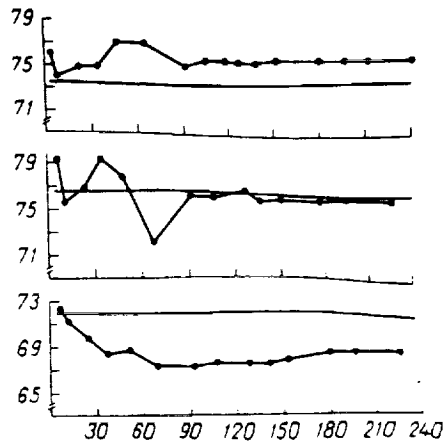


Figure 1: Changes in body weight of cosmonauts during a 237-day flight on Salyut-7-Soyuz-T.  
Abscissa —days of flight; ordinate — body weight (in kg)

Figure 2: Changes in mean values of end diastolic volume (a), end systolic volume (b), stroke volume (c), ejection fraction (d), cardiac output (e), and diameter of the left auricle (f) in crewmembers before, during and after a 237-day flight on Salyut-7-Soyuz-T  
White columns — preflight, black columns — inflight, hatched columns — post flight;  
1,2,3 — crewmembers



## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

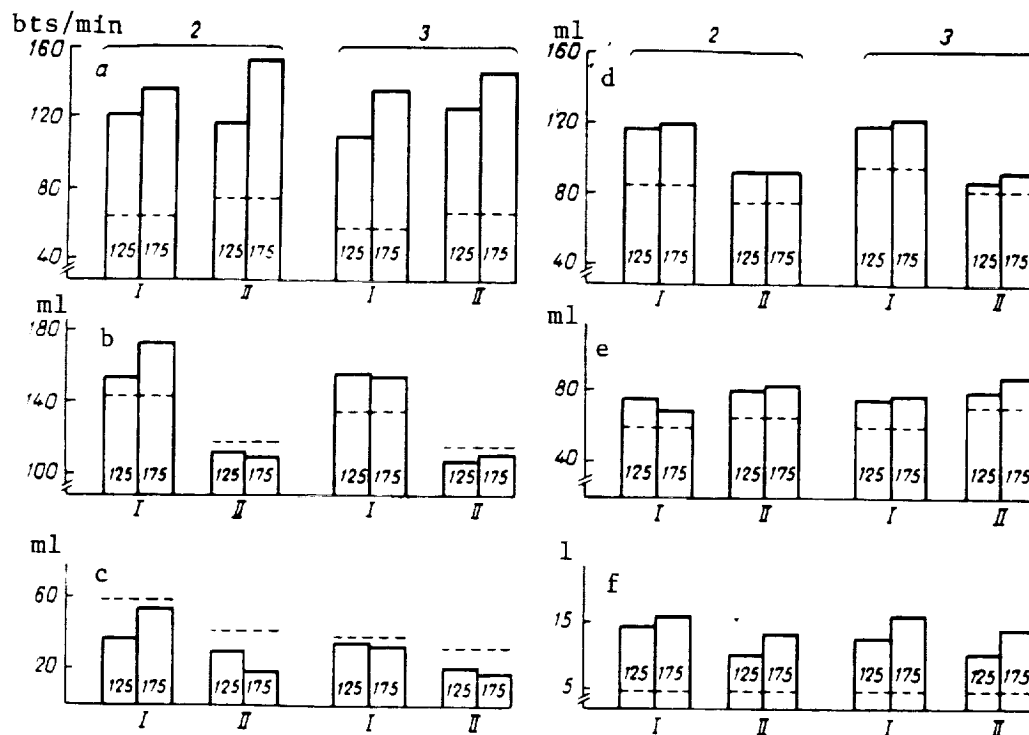


Figure 3: Change in mean values of heart rate (a), end diastolic volume (b), end systolic volume (c), stroke volume (d), ejection fraction (e), and cardiac output (f) in crewmembers exercising before and during a 237-day flight on Salyut-7-Soyuz-T

Numbers in the columns indicate physical workload. 2, 3 — crewmembers. I — preflight, II — postflight

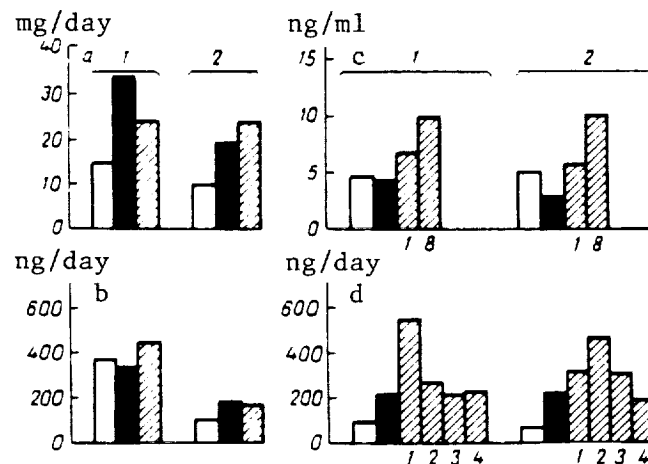


Figure 4: Change in renal excretion of aldosterone (a), 11-desoxycortisone (b), ADH in blood (c) and urine (d) in crewmembers during a 237-day flight on Salyut-7-Soyuz-T

White columns — preflight, black columns — days 216-219 of flight; hatched columns — postflight (Arabic numbers below columns indicate day of flight [sic.], or reaptation period), 1, 2 — crewmembers

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1232(28/90)\*Kazakova RT, Katuntsev VP.

*State of intracardiac and systemic hemodynamics in healthy humans exposed to a weightlessness simulation.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 15-17;1989.

[14 references; 4 in English]

Cardiovascular and Respiratory Systems, Hemodynamics, Intracardiac and Systemic Humans, Males

Weightlessness Simulations, Immersion, Hypokinesia with Head-Down Tilt

**Abstract:** The goal of this work was to evaluate the pumping and contractile functions of the left ventricle in humans exposed to combined water immersion and head-down tilt, simulating weightlessness. Subjects were six apparently healthy males aged 30-36. During the day, they underwent water immersion and during the night head-down tilt ( $-6^{\circ}$ ). Echocardiography was performed in the M-mode from the aorta to the apex along the longitudinal axis of the heart on days 1-6 of treatment. Echocardiography was used to determine heart rate, and left ventricular end systolic and diastolic dimensions. These data were used to derive left ventricle end systolic and diastolic volumes and their indices. Circulatory stroke volume and stroke index, ejection fraction, cardiac output, cardiac index, the degree of shortening of the front-back dimension of the left ventricle during systole, and rate of circumferential fiber shortening were also computed. In addition, blood pressure was measured and total peripheral resistance computed. The results were processed and tested using the t test.

During the first 3 days, the treatment produced a gradual decrease in end diastolic volume index, ejection fraction, shortening during systole, and rate of circulatory shortening. At the same time, stroke and cardiac indices decreased and peripheral resistance increased. The index of end systolic volume and heart rate showed a tendency to decrease. Mean blood pressure was virtually unaltered. Maximal shifts in hemodynamic parameters occurred at the end of day 2. On days 4, 5, and 6 of treatment the changes noted above began to level out, and by the end of the study all parameters were approaching baseline. However, in the majority of subjects, index of end diastolic volume, and stroke and cardiac indices were still below baseline.

The authors conclude that the treatments used lead to marked functional changes in intracardiac and systemic circulation that are cyclic in nature and are a function of duration of treatment. The deficit in venous return of blood noted in all subjects on days 1-3 is argued to be a compensatory response to the initial redistribution of blood. Evidently, due to reactions of the cardiac volume receptors and the intrasternal vasculature to "excess" intrathoracic volume of blood, fluid-electrolyte metabolism is disrupted, leading to fluid loss. Under conditions of immersion, fluid loss has been found to peak during days 1-3 and by day 5 has approached normal. Loss of fluid leads to decreased circulating blood volume and decreased venous flow to the left heart. It is argued that decrease in left ventricle end diastolic volume, i.e., deficit in venous return of blood, such as was noted in this experiment in all subjects, would serve as one of the first manifestations of cardiovascular deconditioning in cosmonauts in space.

Table: Parameters of intracardiac and systemic hemodynamics in humans exposed to a combination of immersion and hypokinesia with head-down tilt

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

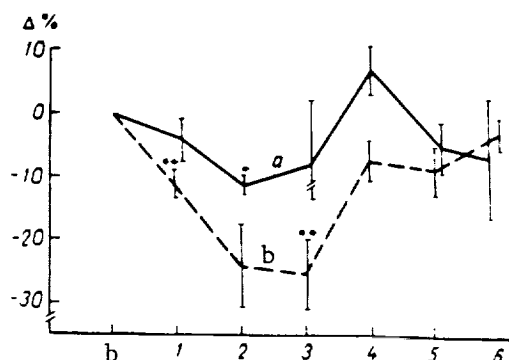


Figure 1: Change in the index of end systolic (a) and end diastolic (b) volume of the left ventricle

Here and in Figure 2: abscissa — time in days; ordinate — value of parameters (in % of baseline); \* —  $p < 0.05$ . \*\*  $p < 0.005$  compared to baseline

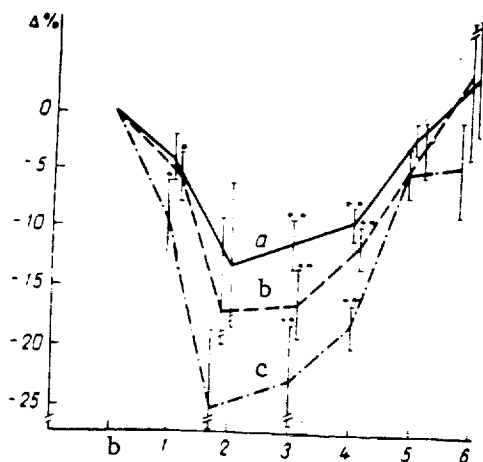


Figure 2: Changes in parameters of contractile capacity of the myocardium of the left ventricle  
 a — ejection fraction; b — extent of shortening of the front-back dimension of the left ventricle; c — rate of circulatory shortening of myocardial fibers

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

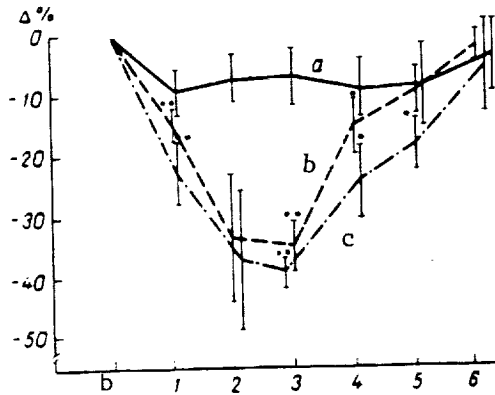


Figure 3: Change in heart rate (a), stroke index (b), and cardiac index (c).

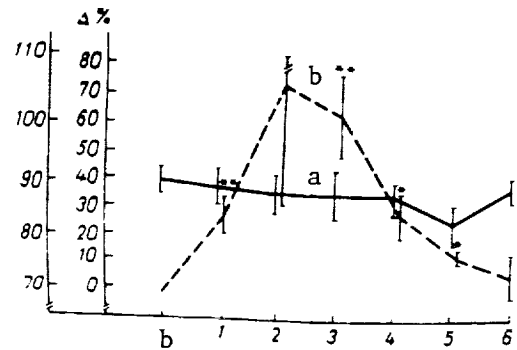


Figure 4: Changes in mean blood pressure (a) and total peripheral resistance (b)  
 Ordinate: left — BP (in mm HG), right — total peripheral resistance (in % of baseline)

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1233(28/90)\* Buzulina VP, Popova IA, Vetrova YeG, Nosova YeA.

*Interaction of cardiorespiratory and metabolic responses of humans to graded exercise.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 17-20;1989.

[16 references; 8 in English]

Cardiovascular and Respiratory Systems, Metabolism

Humans, Males

Physical Exercise, Graded, Horizontal

**Abstract:** Subjects were 9 healthy males, aged 25-40, each of whom performed graded physical exercise in a horizontal position on a specially equipped bicycle ergometer. Work started at a level of 450 kgm/min and increased by 150 kgm/min every 3 minutes until exhaustion. During the test, oxygen consumption and CO<sub>2</sub> production were recorded in liter/min; heart rate and pulmonary ventilation were also measured. Amount of work performed and maximal oxygen consumption (in liters per minute and in ml per minute per kg body weight) were recorded as well. After each level of exercise, blood was taken from the ulnar vein through an implanted needle. Concentrations of lactate, pyruvate and glucose were measured enzymatically. Activity of lactate dehydrogenase and NADP-dependent isocitrate dehydrogenase was measured in venous blood serum. Total oxygen debt was computed from the dynamics of oxygen consumption during recovery. Moment of onset of anaerobic metabolism was found using graphic methods. Data recorded at rest, at onset of anaerobic metabolism, and at termination of exercise were submitted to analysis and tested using the t-statistic.

Results showed that the subjects tolerated the exercise test satisfactorily. They did not complain of adverse symptoms after its completion. When exercise was terminated due to exhaustion, heart rate and pulmonary ventilation values were high, suggesting substantial stress on the cardiorespiratory system. Maximum oxygen consumption per minute per kg body weight peaked at 39.6 ml for the group, which is substantially lower than that for subjects exercising daily. Concentration of glucose after exercise terminated was depressed by 15% compared to baseline, suggesting that at the work rate attained supply of carbohydrate substrate was adequate in spite of the cardiorespiratory stress. Increase in lactate exceeded 4 mmole/liter attesting to activation of anaerobic metabolism. Lactate concentration was highly correlated with amount of work performed.

The estimated exercise load at which anaerobic metabolism began was 13% lower when based on lactate concentration than on pulmonary ventilation and difference in time of onset of anaerobic metabolism was 2-3 minutes. When anaerobic processes were triggered, lactate increased by 370% and pyruvate by 133%, while activity of lactate dehydrogenase increased by 20.3% and of isocitrate dehydrogenase by 17.5%. Increased lactate dehydrogenase activity near the onset of anaerobic metabolism was highly correlated with pulmonary ventilation ( $r=0.74$ ), gas exchange (0.63), and heart rate (0.64), while changes in isocitrate dehydrogenase were correlated only with gas exchange ( $r=0.73$ ). Correlations were maintained for lactate dehydrogenase at termination of exercise, but isocitrate dehydrogenase activity correlated only with VCO<sub>2</sub> at that point. While lactate dehydrogenase continued to increase, isocitrate dehydrogenase had dropped. This lack of parallelism in the two parameters indicates altered relationship between oxidative and glycolytic energy formation. The tendency for exercise-associated increase in isocitrate dehydrogenase activity to reverse itself near the point where anaerobic metabolism begins could serve as an additional criterion for the beginning of glycolysis.

Table 1: Changes in cardiorespiratory and metabolic parameters at various levels of exercise

## **CARDIOVASCULAR AND RESPIRATORY SYSTEMS**

Table 2: Comparison of characteristics of onset of anerobic metabolism determined by concentration of lactate and pulmonary ventilation

Figure: Activity of lactate dehydrogenase and isocitrate dehydrogenase in blood serum

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1238(28/90)\* Chernysheva ON.

*Lipids in the cell membrane of the heart in rats after multiple exposure to an alternating magnetic field with frequency of 50 Hz.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1):30-31; 1990.

[12 references; 2 in English]

Cardiovascular and Respiratory Systems, Cell Membrane of the Heart

Rats

Radiobiology, Magnetic Field, Alternating

**Abstract:** Subjects in this experiment were 45 outbred white rats. Some of the rats were repeatedly exposed to an alternating magnetic field at commercial frequency of 50 Hz. (15 sessions of 5 hours each) with intermittent generation mode at field strength of 9.4 mT. The remainder of the animals were maintained under analogous conditions with the exception of the magnetic field. The experimental animals were decapitated 20 hours after the end of the last session, with the heart rapidly extracted and placed in a chilled solution of 0.25 M sucrose, buffered with 5mM histidine (pH 7.4). The heart was carefully cleansed of blood and pulverized; 50 ml of the aforementioned solution was added and the mixture was homogenized and centrifuged at 800-g for 20 minutes. The precipitate was resuspended in 15 ml of the solution, and centrifuged twice for 20 minutes at 14,000-g to release the fraction of heavy microsomes and mitochondria. The supernatant, consisting of the light microsomal fraction, was centrifuged for 1 hour at 105,000 g. The purity of the resultant fractions was monitored with an electron microscope. All procedures were performed at cold temperatures. The precipitate obtained was poured into 1 ml of the initial solution, suspended, the amount of protein in the homogenate determined, and a mixture added to identify lipids. Lipids were extracted, identified, and measured using thin-layer chromatography of neutral lipids and phospholipids.

In rats exposed to the field, certain lipid components had accumulated in the heart, particularly triacylglycerides (by 47.5%), free fatty acids, and cholesterol esters (by 58 and 28.5%, respectively). Phospholipids were elevated by 15% and cholesterol level was somewhat depressed, decreasing cholesterol the phospholipid ratio to 35.4%. The phospholipid spectrum was unaltered, but concentration of phosphatidyl inositol in cardiac cell membranes was 49% above the level in irradiated rats. The authors suggest this may be a compensatory response to the potentially adverse changes in ultrastructure of the lipid component of the cell membrane in the heart, serving to inhibit initiation of free-radical processes.

**Table:** Composition of the cell membranes of the hearts of rats after multiple exposure to an alternating magnetic field with frequency of 50 Hz

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1243(28/90)\* Ivanov SG, Markova LI.

*The use of the method of "dry" immersion in treatment of hypertensive crisis.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 40-42; 1990.

[16 references; 1 in English]

Cardiovascular and Respiratory Systems, Hypertensive Crisis  
Humans, Patients, Essential Hypertension, Males and Females  
Dry Immersion, Treatment

**Abstract:** A study was performed on 26 patients (14 males and 12 females) suffering from stage II essential hypertension. Age ranged from 46 to 68 for women and 35 to 59 for men. Duration of the disease ranged from 2 to 23 years; some subjects suffered from other diseases as well. Subjects had not responded satisfactorily to drugs. Central hemodynamic parameters were measured using integral impedance plethysmography. Blood concentrations of aldosterone, glucagon, hydrocortisone, ACTH, calcitonin, and insulin were measured radio-immunologically. At the moment of the crisis and after treatment, EKGs were recorded and blood pressure was measured. Subjects were treated by dry immersion (lying on a waterproof sheet in a thermally neutral bath) and were immersed to the level of the costal arch. A cushion was placed under the subjects' heads to raise the rib cage above the surface of the water. The session of dry immersion lasted until blood pressure dropped to an acceptable level, but not longer than 90 minutes.

Subjects could be divided into 2 subgroups on the basis of impedance plethysmographic data. In 21 (group 1) blood pressure increase was accompanied by increased peripheral resistance and decreased stroke volume. In 5 (group 2), stroke volume was elevated while peripheral resistance remained essentially normal. After dry immersion, systolic blood pressure decreased in group 1 from 196.7 to 151.43 and diastolic pressure from 108.1 to 90.2. In group 2 systolic blood pressure decreased by 46.6 mm Hg and diastolic by 14 mm Hg. The hypotensive effect of the treatment was observed in 18/21 subjects in group 1 and 4/5 in group 2. In group 1 immersion led to a significant decrease in peripheral resistance and only small changes in stroke volume. In group 2 stroke volume decreased significantly and resistance only slightly. There were no significant changes in heart rate in either group. Power of the left ventricle decreased in both groups. Immersion led to increased glucagon and decreased hydrocortisone and ACTH in the blood. Activity of aldosterone, calcitonin, and insulin showed a tendency to decrease. Side effects did not occur. The authors recommend dry immersion as a substitute for drug therapy or for use when drug therapy proves ineffective as a treatment for hypertensive crisis.

Table: The effect of "dry" therapeutic immersion on hemodynamic parameters of patients studied



## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1243(28/90)\* Turbasov VD, Artamonova NP, Nechayeva Yel.

***Assessment of bioelectric activity of the heart during head-down tilt using traditional and modified EKG leads.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1):42-44; 1990.

[12 references; 3 in English]

Cardiovascular and Respiratory Systems, Bioelectric Activity of the Heart

Humans, Males, Patients, Atherosclerosis

Hypokinesia with Head-Down Tilt, Countermeasures, Exercise, Muscle Stimulation, Drugs, Equipment and Instrumentation, EKG Leads

**Abstract:** This study used 29 men, aged 26-52, who spent 30 days in a position of head-down tilt (-8°). Group 1 contained 6 apparently healthy men submitted to strict bedrest. Group 2 contained 8 apparently healthy men undergoing bedrest and performing a set of physical exercises using rubber "shock absorber" (bungee?) straps and other exercise equipment, and receiving electric stimulation of the muscle and pharmacological countermeasures. Group 3 consisted of 15 males with signs of atherosclerosis, who were taking vasoactive drugs and eating a special diet. EKGs were recorded simultaneously using 12 standard EKG leads and 3 modified orthogonal leads in the morning in fasting subjects. EKGs were measured during baseline, on days 1, 7, 14, and 28-30 of hypokinesia, and on days 2 and 10 of recovery.

Changes in EKG during hypokinesia with head down-tilt were typical of this treatment and depended on extent to which motor activity was limited and on other prophylactic measures. Changes in subjects of groups 1 and 2 disappeared during the 10-day recovery period, while recovery was not complete in group 3 subjects. Changes were least pronounced in group 2 subjects and then recovery was most rapid. Comparative analysis of EKG changes recorded using the modified and standard leads did not reveal any advantages of the former.

Table: Dynamics of EKG parameters during hypokinesia with head-down tilt

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1245(28/90)\* Korolev AB.

***Methods for measuring intracranial blood and cerebrospinal fluid circulation in chronic experiments involving induction of decompression sickness.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1):47-49; 1990.

[2 references; 1 in English]

Cardiovascular and Respiratory Systems, Circulation, Blood, Neurophysiology, Brain,  
Cerebrospinal Fluid

Rabbits

Decompression Sickness

**Abstract:** This paper describes a method for directly observing the responses of the vasculature of the cerebral cortex and studying circulation of cerebrospinal fluid through a transparent window in the bones of the skull of animals. Rabbits were used as subjects. The operation to create the window involved two steps. First, anesthetized animals were scalped; 3-5 days later the bone of the skull was sterilized and a opening drilled in it 200 mm in diameter to the level of the dura mater. The dura mater and arachnoid membrane were parted to allow observation of arteries and veins of the cortex within the trepanned opening as well as of gas bubbles passing through the sagittal sinus. The hole was covered with transparent shock-resistant polystyrene. The implant was fixed with screws to the perimeter of the opening. The window was made airtight and prolapse of the brain into the opening was prevented with drugs. The animals were given a course of antibiotics and the wound was treated regularly. The experiments in a barochamber were begun 5-7 days after the operation. A special restraining device was attached to the screws in the animal's skull, so that the opening could be seen through the barochamber window. Observations were recorded with a video system. Three experiments were performed on unanesthetized rabbits, in which they descended to 11 atm and remained for 60, 40, and 30 minutes and then were rapidly returned to 1 atm and observed until they ceased to breath. The experimental method used revealed initial formation of gas in the veins of the brain always preceded the formation of gas bubbles in the cerebrospinal fluid and spasms of arteries and veins. No gas emboli were ever observed in the arteries. The authors conclude that this methodology is satisfactory for studying intracranial circulation of blood and cerebrospinal fluid and the processes occurring in these fluids when decompression sickness is induced.

Figure 1: Overall view of an animal with implanted "window"

Figure 2: Vasculature of the brain, sagittal sinus, observed through the "window"

Figure 3: Mount for fixing the head of the experimental animal in the barochamber

Figure 4: A system for observing and recording EKG, respiration rate, and video information

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1278(28/90)\*\* Nekhayev AS, Andriyenko Yul.

*Criteria of endurance of a hypercapnic-hypoxic test.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 46-48; 1990.

[3 references; none in English]

Cardiovascular and Respiratory Systems, Endurance Criteria

Humans, Men, Individual Differences

Hyperoxia, Hypercapnia

**Abstract:** A total of 84 apparently healthy men, aged 18-34, were subjected to a rebreathing procedure. A respiration recorder was attached to the intake hose of the rebreathing apparatus and a pulse recorder to the earlobe. The following parameters were recorded: respiratory minute volume, respiration rate, heart rate, and blood pressure. In the first part of the study (26 subjects) the rebreathing procedure continued until the subject felt himself unable to continue. In the second portion of the study (58 subjects) rebreathing was halted on the basis of respiratory minute volume. Physiological parameters were measured during minutes 1 and 3 before the test and every minute during it. Student's *t* was used to test data statistically.

In the first phase of the study, endurance time varied from 5 to 9 minutes, during which systolic blood pressure and heart and respiration rate increased. Diastolic blood pressure did not change significantly. Respiratory minute volume increased in some subjects and decreased in others during minute 1 of rebreathing, and beginning in minute 2 increased in all subjects. At the point of maximum endurance, respiratory minute volume was 51.2 to 84.0 l/min, having increased from the previous minute by 4.8 to 29.7 l/min. Subjective symptoms at the endurance limit included extreme difficulty breathing, throbbing of the temples, pain in the forehead, perspiration, and hyperemia of the face. These symptoms developed relatively rapidly, approximately 1 minute before the test was halted. One to 2 minutes before acute respiratory failure developed, respiratory minute volume exceeded 40 liter/min and had increased by 10 l/min or more over the preceding minute. In 84.6% of the subjects discomfort arose 1 minute after respiratory minute volume reached critical value. In the second phase of the study, value of respiratory minute volume was used as a basis for discontinuing the procedure. In this phase, no subjects experienced adverse symptoms.

Subjects in all experiment phases were divided into five groups on the basis of their endurance time (with group 1 having the lowest endurance). All subjects showed increases in respiratory minute volume, systolic blood pressure, and heart rate during the procedure. During the last minute of rebreathing values of heart rate and systolic blood pressure were higher in the two groups with the lowest endurance. Parameter changes underwent two phases, a relatively smooth gradual increase in respiratory minute volume and systolic blood pressure, followed by more precipitous increases in these parameters. These phases are termed compensation and subcompensation. The higher the endurance time of a subject the greater the increase in minute volume over baseline. Similar patterns occurred for the other two parameters. For a rapid evaluation of potential tolerance of rebreathing the authors suggest a modified cardiorespiratory index in which respiration rate is replaced by minute volume:

$$CRI = \frac{HR \cdot \text{Systolic BP}}{RMV} \cdot 10^{-2}$$

Table: Dynamics of respiratory minute volume during rebreathing

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

P1279(28/90)\*\* Savina VP, Ryzhkova VYe, Nikitin Yel, Balandina TN, Bragin LKh, Sivuk AK, Bychkov VP, Bobrova GG.

***The composition of expired gas, gas and energy exchange, and biochemical parameters in blood and urine of humans under conditions of long-term exposure to hypercapnia and hypoxia.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):49-51; 1990.

[11 references; none in English]

Cardiovascular and Respiratory Systems, Expired Gas, External Respiration, Biochemical Parameters, Metabolism, Lipid Peroxidation, Nitrogen Metabolism

Humans, Males, Older Subjects

Hypercapnia, Hypoxia, Pressurized Environment, Long-Term

**Abstract:** Four healthy men (aged 41-59) spent 40 days in a pressurized hypercapnic environment. Throughout the experiment the temperature was maintained at 19-23°C, with relative humidity of 30-70%, oxygen composing 19-19.5% of the atmosphere, and carbon dioxide 1.1-1.5%. On days 21-22 and 38-39 the level of carbon dioxide was increased to 4% and oxygen decreased to 17%. The period over which hypercapnia increased to this level was approximately 26 hours the first time and 40 hours the second. Subjects consumed a diet consisting of canned products with total caloric value of 2982. Gas chromatography was used to analyze expired gas for propane, propylene, pentane, isopropanol, methanol, acetylaldehyde, acetone and ethanol. External respiration function and gas and energy exchanges were studied using the "Spirolit-2" device manufactured in the GDR. Acid-base status and blood gases were also studied. Malonic dialdehyde, a secondary product of lipid peroxidation, was measured in venous blood, while the catalase activity of blood, lactate, pyruvate, and urea was measured in capillary blood taken from the finger. Concentrations of total nitrogen, ammonia, urea, creatinine, and uric acid were measured in daily urine as indicators of nitrogen metabolism. Nitrogen balance and a parameter of protein nutrition were calculated. Student's t for paired measurements was used to test results for significance.

Activity of lipid peroxidation was evaluated on the basis of level of carbohydrates in expired gas, pentane and isopropanol in the blood, and also levels of secondary products of lipid peroxidation in blood plasma. When atmospheric carbon dioxide was increased to 4%, carbohydrate fractions increased in expired gas. This increase was more pronounced during the second, more gradual increase in carbon dioxide level. This suggests that there is a change in the ratio of components of lipid peroxidation due to accumulation of the unoxidized products of metabolism. This is confirmed by the fact that the formation of malonic dialdehyde in blood plasma increased, peaking on days 22 and 39. The peak was higher on day 39 than 22. There was a statistically significant correlation (+0.99 sic.) between malonic dialdehyde in blood plasma and pentane and isopropanol (measured together) in expired gas. Catalase activity did not change during the chronic hypercapnia exposure, but did decrease significantly at the end of the first acute increase. Erythrocyte levels changed analogously. Blood lactate change pattern was the inverse of changes in malonic dialdehyde. When carbon dioxide levels increased to 4%, lactate decreased by 30 and 33%. This parameter provides information about level of anaerobic performance and glycolysis. There was a negative correlation of -0.76 between levels of malonic dialdehyde and catalase, an important element of the antioxidant system neutralizing the negative effects of endogenous hydroperoxides. Increased hypercapnia induced a twofold increase in pulmonary ventilation. Gas exchange increased by 20 and 32% for the two acute hypercapnic periods. Changes in acid-base status and blood gases conformed to a picture of pulmonary acidosis during the acute hypercapnia period. The acute periods had virtually no effect on renal excretion of nitrogen metabolism end products, but their excretion was somewhat depressed compared to baseline during the recovery period.

## CARDIOVASCULAR AND RESPIRATORY SYSTEMS

The changes occurring in this experiment using older subjects are analogous to those observed in younger subjects under the same conditions. Changes are described as not exceeding the adaptive norms. Normalization occurred within 1 week after the experiment terminated.

Table 1: Pattern of changes in catalase, lactate, and erythrocytes in subjects

Table 2: Pattern of change in parameters of external respiration, acid-base status and blood gases in subjects

Table 3: Dynamics of excretion of end products of nitrogen metabolism in subjects in a pressurized environment with increase in level of carbon dioxide in the atmosphere up to 4%

Figure: Dynamics of total concentration of peptane and isopropanol in expired gas and malonic dialdehyde in blood in subjects exposed to varying levels of hypercapnia

## DEVELOPMENTAL BIOLOGY

### **SPECIAL FEATURE: *The First Baby Born in Space: The Unique "Incubator-2" Experiment is a Success***

Translation of an article by I. Nekhamkin in Sovetskiy Soyuz: June 1990

An extraordinary event took place on March 22, 1990, the first day of the astronomical spring: in orbit above the Northern hemisphere of the Earth: a gray and brown egg cracked open and out popped a baby quail...

The first Earthling born in space — how can the significance of such an event be assessed today? Undoubtedly it will have enormous importance, importance that will increase with time, for practical cosmonautics as well as for fundamental research in biology, embryology and other sciences concerned with development and vital processes of living things. Such profound studies are not far off in the future. Their foundation — the first experiments in space biology — was laid down at the dawn of the space era, more than three decades ago. At that time, the first dogs flew in space on Soviet satellites, paving the way for the flight of humans. From that time on, biomedical experiments were performed on specialized biosatellites, as well as on board space stations. Higher plants, seeds, frog ova, newt eggs, flies, dogs, primates — all were used to study the effects of space flight factors, especially weightlessness.

Of course, the world scientific community is familiar with the results of these experiments, although they did not make a great impression on ordinary people who are far removed from the subtleties of biological research. However, anyone who knows even a little about the prospects for space research has been more than a little interested in them. The fact is that the founding fathers of cosmonautics, especially Konstantin Tsiolkovskiy, predicted that flight durations would increase and humans would have to learn to reproduce increasingly better analogues of the familiar environment of Earth on spacecraft. Plants would be grown to provide cosmonauts with fresh vegetables to eat and oxygen to breathe. Certain small domestic animals would be raised, perhaps rabbits or chickens, to add meat and eggs to the diet.

And although such space flights are still in the future (the manned Mars mission is projected for some time after the turn of the century), biologists are continuing, step by step, to create a "little bit of the Earth" in space. One of these steps was an experiment performed as early as 1979 on the Soviet biosatellite COSMOS-1129. At that time Soviet and Czechoslovak specialists put an incubator into orbit to study the possibility of a chick embryo developing in weightlessness. However, it was stipulated that the egg would hatch after return to Earth, rather than in space. The experiment was encouraging and the scientists continued to move closer to their goal of hatching a chick in space. For this purpose the Incubator-1M device, developed by Soviet and Czechoslovak scientists, was installed on board the Mir complex. It contained several dozen quail eggs and provided the required conditions for hatching. A chamber with systems to provide ventilation, food, warmth and waste disposal awaited the newly hatched birds. All the apparatus were automated and equipped with monitoring and control devices.

When the crew was already in orbit, the transport ship delivered a container with 48 eggs of the Japanese quail (a species common not only in Japan, but in our far east). The cosmonauts had to place the eggs in the incubator and wait until they hatched.

This minute arrived: eight quails in all hatched. What happened to the other eggs will be discovered through the study of all the experimental material returned from orbit. Scientists of various nations have requested to be allowed to participate in this research with Soviet biologists — it is truly a unique project. After all, for the first time scientists will be able to observe all the stages of embryonal and postembryonal development of a living creature in weightlessness.

## DEVELOPMENTAL BIOLOGY

There were many doubts about whether this process would follow a normal course. Since the end of the last century, scientists of all nations have been studying the problem of how the extremely complex structures of a living creature — tissues, organs, functional systems — develop during the incubation period from an essentially structureless egg. Today this process is more or less understood as it occurs on Earth. And it is well known that the egg itself is not indifferent to the force of gravity. For example, its first divisions occur along the vertical and horizontal axes. What would happen in weightlessness, in which there is neither "up" nor "down"?

The waiting period was full of stress. But on the 17th day, at the normal time for quail, the first shell cracked there in orbit. To the delight of the biologists the same thing occurred in the control incubator on Earth, the first baby quail appeared — the "partner" of the one in space!

But let us return to his brothers in orbit.

"One after another, eight little quails hatched," said the director of the laboratory of the Institute of Biomedical Problems, Tamara Gureyeva. "But two were unable to extricate themselves from the shell. The six that were left began their short lives in space.

"I remember on that day in the Central Flight Control Administration, on an enormous television screen there was an unprecedented transmission. Cosmonaut Anatoliy Solov'yev showed us the fluffy yellow and black baby quail. We saw a perfectly normal, healthy baby bird. Sitting in the palm of the cosmonaut's hand, he blinked from the bright lights, turned his head, pecked at the feeding tube, picking out the bigger crumbs, and, throwing his head back, swallowed them."

But when he was returned to his cage, he found life very difficult: the air stream that the engineers had counted on to keep the chick on the grid floor and maintain stability did not work. And for that reason the newborn "cosmonaut" was compelled to perform acrobatic back flips. When he did touch the floor for a moment, for some reason he kicked out with his feet and again soared up to the ceiling. He did not have a grasping reflex, and it was hard for him to live, although the cosmonauts tried to give him stability by wrapping him in strips of cloth.

Sadly, after 6 days had elapsed, only two baby quails were still alive. Subsequently, they too died. All the chicks and eggs with embryos in various stages of development became important scientific material for biologists. The engineers too were given something to think about: how are they going to "teach" the newborn birds to walk on the floor?

"But, after all, the main thing has been proven," said Dr. Yevgeniy Shepelev. "We have banished doubts. Weightlessness is not an insurmountable impediment to the development of life. I think the study of the materials on Earth will confirm our optimism. And it is with this same feeling that one of the initiators of this experiment, academician of the Czechoslovak Academy of Sciences, Koloman Bodya, returned home from the USSR. For precisely this reason we can now plan new more complex experiments with confidence. For example, we can put quails in orbit, obtain eggs from them and then produce a second generation of space stock. We must keep moving forward!"

## PAPERS:

P1275(28/90)\*\*Goncharov SS, Shekhova AN.

### *Hormonal response of the steroid-producing glands of female hamadryas baboons to long-term hypokinesia.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):34-37; 1990.

[12 references; 4 in English]

Endocrinology, Reproductive System, Steroids, Biological Rhythms, Menstrual Cycle, Diurnal Rhythms

Primates, Hamadryas Baboons, Female

Hypokinesia, Long-Term

**Abstract:** Research was performed on 12 fertile female hamadryas baboons with stable two-phase menstrual cycles of 28-37 days in duration. During the baseline period the animals were maintained in cages under conditions of restricted movement. Subsequently they were immobilized in a horizontal position for 28 days. They were also studied under conditions similar to baseline during recovery (days 50-60). Hypokinesia was induced with a special method of restraint on animals in horizontal position. Animals were divided into two groups on the basis of phase of the menstrual cycle an animal at onset of hypokinesia, with six animals in each group. For group 1 restraint began in the follicular phase (day 6-7 of the menstrual cycle), group 2 in the luteal phase (day 6-7 after ovulation). Blood in a volume of 4-5 ml was taken from the ulnar vein throughout the research period at a rate of 1-3 times a week. To evaluate the reactivity of the adrenal cortex to acute stress, blood was taken immediately before restraint (0) and then in hours 1, 3, 6, 24, 48, and 72 after it began. During the period of readaptation, blood was taken immediately upon release from restraint (0) and then 1, 3, 6, 24, 48 and 72 hours after release. Plasma was obtained by centrifugation and stored at -20°C. Hydrocortisone was measured using concurrent binding with protein. Estradiol, progesterone, 11-oxy corticoid and corticosterone were measured using radioimmune assay with antiserum. Concentrations of 17-hydroxyprogesterone and 17-oxypregnenolone were evaluated radioimmunologically, preceded by column chromatography. Data were tested using Students' t.

Results showed that, regardless of menstrual phase at the start of the experiment, long-term hypokinesia evoked a two-phase response in the adrenal cortical system. On day 1, hydrocortisone, estradiol, 17-hydroxyprogesterone, and 17-hydroxypregnenolone were elevated. Maximal increases were noted during hours 1-3 after treatment. Levels remained elevated during the next 48 hours in the follicular phase and during the next 3 hours in the luteal phase, then returned to normal 72 and 6 hours after the beginning of the experiment, respectively. Maximal decrease of hormone levels was observed on days 7-10. Depressed levels continued throughout the hypokinesia period and the first 2-3 weeks of recovery. These results are attributed to stress response. Animals in the follicular period, when hypokinesia began, responded by greater excretion of corticosteroids than animals in the luteal phase. In both menstrual phases, hypokinesia tended to dampen diurnal rhythms in corticosteroid excretion, while the general shape of the diurnal curve remained similar. Long-term hypokinesia also depressed the hormonal function of the ovaries. However, the nature of changes in sex steroids depended on phase of menstrual cycle. If animals were in the follicular phase when treatment began, level of estrogens decreased to a minimum 40-50% of baseline on days 2-3 of the experiment. Changes in progesterone were highly correlated with level of hydrocortisone. For animals in the luteal cycle, hypokinesia induced premature luteolysis, accompanied by progressive decrease of progesterone in blood and shortening of the luteal phase of the cycle by 6 days. Pattern of changes in estradiol was similar to those in progesterone. In all cases decreases in these two hormones continued for the first 2-3 weeks of the readaptation



period. Circadian rhythms in secretion of ovarian hormones were disrupted. Full recovery in all hormones affected occurred by 3-4 weeks into the recovery period.

The authors conclude that their research attests to significant shifts in synthesis and secretion of steroid hormones in female baboons exposed to long-term horizontal hypokinesia. This leads to marked steroid imbalance, which could affect pathogenesis of hypokinetic disease and disrupt reproductive function.

Table: Magnitude of response of corticosteroids in apes to acute stress induced by the beginning of hypokinesia or the subsequent period of readaptation as a function of phase of menstrual cycle

Figure 2: Circadian rhythms of level of corticosteroids in blood plasma under conditions of free (filled circles) and restricted (empty circles) motor activity begun in the follicular and luteal phases of the menstrual cycle

Figure 4: Circadian rhythms in the level of sex hormones in plasma of hamadryas baboons under conditions of free and limited motor activity begun in the follicular or luteal phase of the menstrual cycle

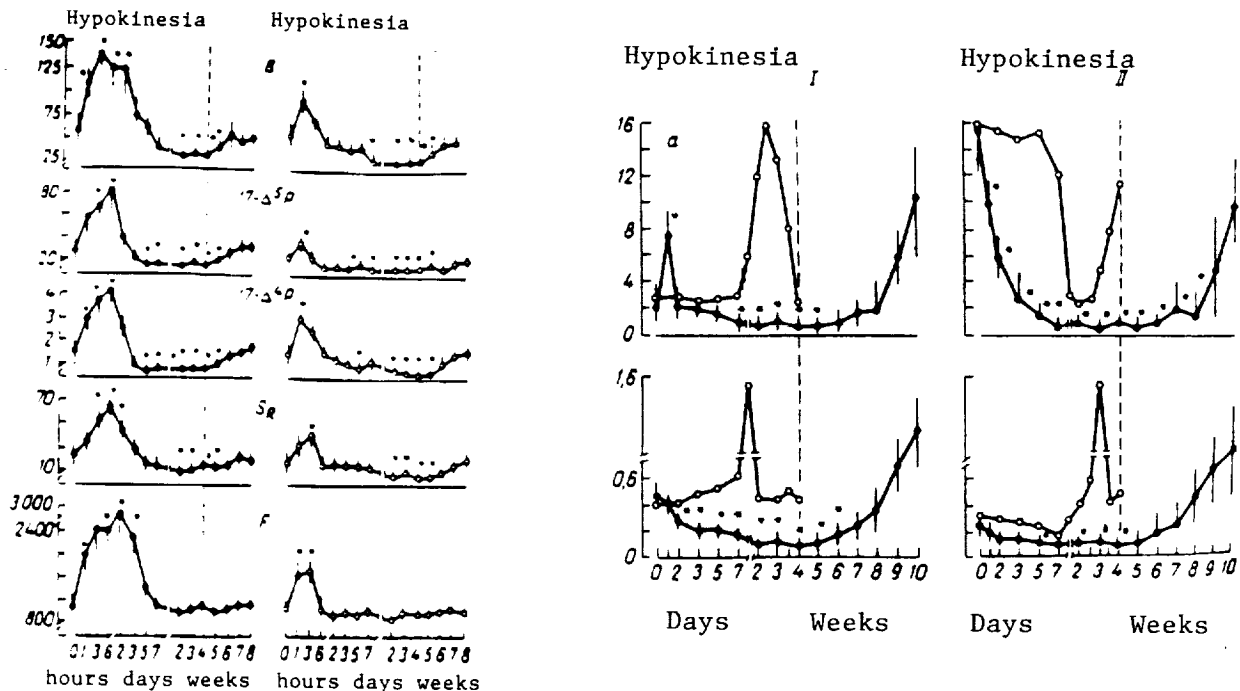


Figure 1: Dynamics of concentration of hydrocortisone, 11-oxyhydrocortisone, 17-hydroxyprogesterone, 17-hydroxypregnenolone, and corticosterone in blood plasma of hamadryas baboon under conditions of long-term horizontal hypokinesia begun in the follicular (filled circles) and luteal (empty circles) phases of the menstrual cycle

Ordinate - steroid concentration in blood plasma. \* - differences significant compared to control

Figure 3: Dynamics of sex hormones (in nmole/l) in blood plasma of baboons under conditions of free (empty circles) and limited (filled circles) motor activity begun in the follicular (I) and luteal (II) phase of the menstrual cycle  
a - progesterone, b - estradiol

P1277(28/90)\*\* Lakota NG, Kvasova MM, Larina IM, Vorob'yev DV, Ostrovskaya GZ.  
*Efficacy and realization mechanisms of the protective effects of sidnocarb under conditions of experimental weightlessness and chilling.*  
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.  
 24(2):42-46; 1990.  
 [43 references; 16 in English]

Endocrinology, Catecholamines, Thermal Protection

Humans

Immersion, Chilling, Pharmacological Countermeasures, Sidnocarb, Neurophysiology

**Abstract:** The drug sidnocarb (N-phenylcarbamoyl-3-[B-phenylisopropyl]-sydnominine) is a CNS stimulant that acts primarily on the noradrenergic system and selectively affects the limbic structures. It has been found to positively affect performance in high and low temperatures. It has been suggested that due to its thermoprotective and psychoactive effects it might be suitable for improving performance of cosmonauts under emergency conditions. The present study analyzed the results of biochemical, radioimmune and radioligand analyses to elucidate the mechanisms underlying the pharmacological effects of sidnocarb in simulation of the effects of weightlessness and chilling. Six volunteers immersed in ice-cold water were given five 0.03 g doses of either sidnocarb or a placebo 1, 3, 6, 9, and 12 hours after beginning of exposure. Parameters measured included body and skin temperature, oxygen consumption and pH of capillary blood. In an additional study, a total of 11 volunteers were immersed in water in natural winter conditions at an effective temperature of -10-29°C for 48 hours. Five individuals were given a placebo and 6 sidnocarb in a high daily dose. During the baseline period and in hours 15, 22, and 39 of exposure, the total concentration of catecholamine substances was measured in venous blood, as well as lactic acid, potassium and sodium ions in erythrocytes. Additional subjects spent 48 hours under conditions of "suit immersion," receiving a placebo and sidnocarb in a dose of 0.01 g twice a day during the first half of the day. Operational medical monitoring was based on parameters of heart rate, sublingual body temperature, blood pressure, and responses to a questionnaire. During baseline and after 1 and 2 days of exposure, concentrations of ACTH, PTH, calcitonin, STH, hydrocortisone, renin, aldosterone, and insulin were measured in blood serum and plasma using radioimmune assay. Glucocorticoid receptors of peripheral blood lymphocytes were studied in peripheral blood, including determination of characteristics (number and affinity) of specific receptors in isolated blood lymphocytes, and also dynamics of receptor regulation during immersion, when sidnocarb or a placebo were administered. The number of highly specific binding sites and the dissociation constant were also recorded using the radioligand method.

In the study in which subjects were immersed in ice-cold water, those receiving the placebo were able to remain for 13 hours, while those receiving sidnocarb were removed after 18 hours, although their rectal temperature had not yet reached critical values. Subjects receiving the placebo displayed a decrease of 3.4°C in body temperature, while energy consumption was triple baseline and oxygen consumption nearly double baseline. Those receiving sidnocarb showed no decrease in temperature until the last 2-4 hours of exposure. Oxygen consumption increased slightly during the first 1-2 hours, but underwent no further increase. Biochemical analysis showed that pH of capillary blood did not increase, while pO<sub>2</sub> increased by 10-12 mm Hg in both groups. Potassium ion concentration was not significantly altered and sodium ions increased by 18-10 mg% in both groups, which is typical of immersion. Diuresis was 1308 ml in the control and 1800 ml in the experimental group. Lactic acid increased in the sidnocarb group and decreased in the placebo group, suggesting activation of glycolysis, the supplier of ATP during cold stress.

## ENDOCRINOLOGY

In the field study involving 48 hours of exposure to cold, rectal sublingual and skin temperature decreases were all less in the sidnocarb group. This same group lost less weight and displayed more diuresis. Administration of sidnocarb increased excretion of catecholamines into the bloodstream. Experimental subjects displayed greater increases in blood concentrations of lactic acid and lower decreases in potassium ions than controls. This is taken as evidence that a higher number of ATP molecules provides more effective forms of energy, leading to lower oxygen demands compared to those of controls.

In the 2-day suit immersion study, control subjects displayed a decrease in body temperature (by 0.6°C) despite thermoneutral conditions. Temperature changes are interpreted as a response to simulated weightlessness. Temperatures increased by 0.2°-0.6° under the same conditions in the sidnocarb group. Compared to control subjects, the sidnocarb group displayed greater increases in ACTH, and greater decreases in hydrocortisone, suggesting the failure of hydrocortisone to respond to ACTH stimulation. Insulin increased in the control group and decreased in the sidnocarb group, possibly due not only to decreased secretion, but to increased tissue uptake. Pattern of changes in PTH and calcitonin suggest additional hypercalcemic stimulation by sidnocarb. Aldosterone increased in the control group, particularly on day 1, but was insignificantly depressed in the sidnocarb group. Renin activity was similar in both groups. Factor analysis of results on hormone regulation using the method of principle components confirmed differences in response of hormones to immersion with and without administration of sidnocarb. Differences suggested that, in the drug group, there was a decreased stress hormone response and decreased activation of hormones that is typically observed when blood circulation is centralized in response to immersion.

Of particular importance is information concerning sensitivity of tissue to effects of glucocorticoids in immersion with or without sidnocarb. When three subjects showing normal number of receptors and coefficients of dissociation were exposed to immersion without drugs, there was evidence of increased number of specific binding sites on a single blood cell and of increased coefficient of dissociation. When the same subjects were given sidnocarb and exposed to suit immersion, no such effects were observed.

The effects of immersion in thermally neutral water on body temperature are attributed to endogenous decreases in heat production as a consequence of altered level of functioning, similar to that observed in microgravity. The authors argue that pharmacological correction, for example with sidnocarb, of decreased heat content of the body may attenuate the "peak" period of adaptive changes and thus improve overall endurance in real and simulated weightlessness. They postulate that sidnocarb acts centrally to attenuate if not block the general stress responses and stimulates production of active forms of catecholamines, primarily noradrenalin, stimulating glycolysis and contractile thermogenesis in the muscles. These effects have sometimes been shown to be sufficient to prevent expenditure of Krebs cycle ATP on heat production and block the two-threefold increase in gas exchanges, such as those observed in subjects exposed to cold without the drug.

Table 1: Mean deviation of parameters of hormonal status (in %) in subjects given sidnocarb or a placebo after 1 and 2 days of suit immersion

Table 2: Results of factor analysis of certain parameters of hormonal regulation on days 0, 1, and 2 of suit immersion in subjects taking placebo and sidnocarb

Table 3: Parameters of sensitivity of specific glucocorticoid receptors of lymphocytes under conditions of 2 days of suit immersion

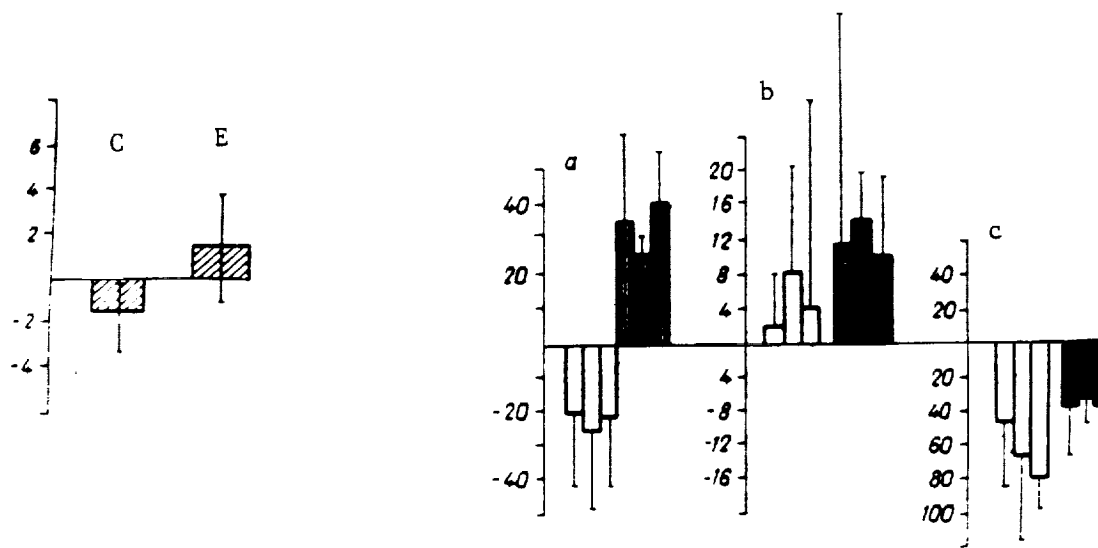


Figure 1: Mean deviations of blood lactic acid (in mg%) after swimming in icy water to endurance limit

C (control) —group receiving placebo (n=5), E (experimental - group receiving sidnocarb (n=6)

Figure 2: Mean deviations of certain biochemical parameters of venous blood on hours 15, 22, and 39 of exposure to natural winter conditions in groups receiving placebo (n=5) and sidnocarb (n=6)

a - sum of catecholamine substances (in ng/mg); b - concentrations of potassium ions in erythrocytes. Light bars - placebo, hatched bars - sidnocarb

Figure 3: Factor structure of concentrations of hormones on days 0, 1, and 2 of exposure to suit immersion in groups receiving placebo (n=6) and sidnocarb (n=4)

P1282(28/90)\*\* Zagorskaya YeA., Rodina GP.

*The responses of the endocrine system and peripheral blood of rats to single and repeated exposure to a pulsed low-frequency electromagnetic field.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 56-60; 1990.

[25 references; 11 in English]

Endocrinology, Adrenal Cortex, Thyroid, Testes

Rats

Radiobiology, Electromagnetic Field, Pulsed, Low Frequency, Immobilization Stress

**Abstract:** This work investigated the effects of a pulsed low-frequency electromagnetic field on the functional activity of certain endocrine glands and the state of peripheral blood of rats, and also on reserve capacities of these systems when exposed to additional stress. Subjects were 300 male Wistar rats exposed to a field generated by "Magniter" devices. The field had a maximum amplitude of induction of 20 mT, and minimal induction of 0.6 mT at the surface of the generator, with pulse duration and interpulse interval of  $10^{-2}$  sec. Induction decreased farther from the surface of the device. Rats were placed in plastic cages under each of which were 7 magniters. The cages were located either at the surface of the magniter or 10 cm from the surface, producing inductance of 20 and 0.1 mT. There was a single exposure, lasting 20 minutes, 1, or 2.5 hours, to inductance of 20 mT. Exposure to inductance of 0.1 mT occurred either once for 2.5 hours or for 6 hours per day for 30 days.

Reserve capacities of the systems of interest were studied by using a supplementary stress simulation involving immobilization of the animals in a spread-eagle position for 5 hours. Immobilization occurred 1 day or 2 months after exposure to the magnetic field. Experimental material consisted of peripheral blood from the tail vein and blood serum obtained after decapitation 1 day or 1 or 2 months after exposure to the field at the same period of the day. Radioimmune assay was used to determine concentration of hormones: corticosterone (CS), free and total thyroxine ( $T_4$ ), triiodothyronine ( $T_3$ ), and testosterone (TS), which were taken as indicators of the functional status of the adrenal cortex, thyroid and reproductive organ. Leukocytes, and certain leukocyte forms — eosinophils, reticulocytes, and erythrocytes — were measured using classical hematological methods. Student's *t* was used to test data for significance.

Total body weight and adrenal weight did not alter as a result of exposure to the magnetic field. One day after 2.5-hour exposure to the lower field level, CS concentration increased by 30-40% compared to control, but no significant changes were found in this parameter after the 30-day exposure. After exposure to the 20 mT field for 20 minutes, concentrations of CS increased by 20-30%. Immediately after 2.5-hour exposure, and on the next day, CS was less elevated and decreased relative to the controls after 1 and 2 months. The stress stimulus led to significant increases in CS in control and experimental rats. However, the response was more pronounced in irradiated rats. Concentrations of thyroid hormones showed similar change patterns. One day after a single exposure to the field at 0.1 mT, total  $T_4$  and  $T_3$  increased by 40-60%, but no changes were noted after a 30-day exposure. After 2 months there was a significant decrease in the level of  $T_4$ . Immediately after a single 20-minute exposure to the 20 mT field,  $T_4$  and  $T_3$  were elevated. Subsequently there was a gradual decrease in the level of these hormones with time. Total  $T_4$  was still depressed 2 months after exposure. Free  $T_4$  was more stable, showing an increase only after single exposure to a 0.1 mT field and 2 months after a 2.5-hour exposure to the stronger field. Immobilization decreased the levels of all three thyroid hormones in control and experimental animals. Previous exposure to the magnetic field affected this response in different ways at different times. After a single and 30-day exposure to the 0.1 mT field, concentration of TS increased by 20-60% and subsequently fluctuated. No

## ENDOCRINOLOGY

changes in this hormone were noted immediately after 20-minute and 2.5-hour exposure to the stronger field. On subsequent days after the longer exposure, TS increased by 40% but showed no changes after 1 or 2 months. Immobilization led to a significant decrease in this hormone in control and irradiated subjects; however, the effect of radiation in a number of instances attenuated the response.

Changes associated with the exposure to the field were generally within the physiological norm for CS and thyroid hormones, but exceeded the norm for TS.

No significant differences attributable to exposure to the magnetic field were found in leukocytes. Responses to immobilization were similar in experimental and control rats. Number of neutrophils increased after exposure of 2.5 hours to the 20 mT field, and number of granulocytes increased by 40% on the day after this treatment. Responses to immobilization involved severe neutrophilia in both control and experimental groups. On the day after the 2.5-hour exposure to the 20 mT field, lymphocyte numbers decreased by 20-30%. This effect persisted for 2 months. After 30-day exposure to the weaker field, eosinophils decreased by 80%, with normalization occurring gradually thereafter. At all three exposures to the stronger field eosinophils increased immediately and then decreased by 60% compared to controls, followed by normalization. Immobilization stress led to severe eosinopenia in control and experimental animals. No changes were noted in erythrocytes or reticulocytes in any experimental condition.

The authors conclude that the immediate (day after) response to the weak magnetic field, involving functional activation of the adrenal cortex, thyroid and reproductive organs without depression of the thymicolymphatic system, is characteristic of "training" type adaptive responses. Long-term exposure to this field led to further increase in the activity of the reproductive organs, and eosinopenia without substantial changes in the adrenal or thyroid glands. The response to a single exposure to a strong magnetic field is described as nonspecific, characteristic of a general response to any very strong stimulus. One and 2 months after exposure to the field, most changes had normalized. However, level of total  $T_4$  and number of lymphocytes remained depressed. Such effects might be related to insufficiency of thyroid hormones or direct effect of the field on lymphoid tissue. The fact that exposure to the field sometimes significantly modified response to immobilization suggests an inadequate stress response.

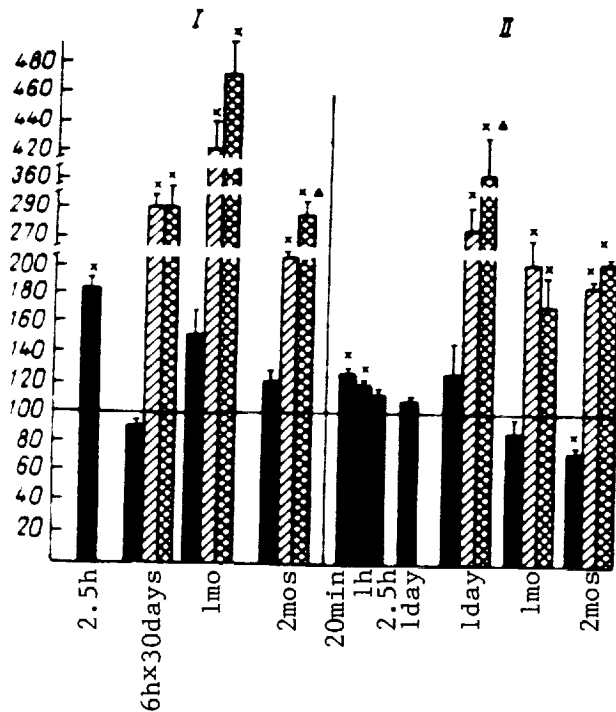


Figure 1: Concentration of CS in blood serum of rats after exposure to pulsed electromagnetic field (black bars), acute stress (hatched bars), and combined effects of the field and stress (cross-hatched bars)

Abscissa: duration of exposure and time after exposure to field; Ordinate: concentration of CS (in % of control), I - field intensity of 0.1 mT; II - field intensity of 20 mT. \* difference significant compared to control,  $p = 0.04$ . triangle - difference significant compare to stressed control (without magnetic field),  $p = 0.05$ .

Figure 2: Concentration of thyroid hormones in blood serum of rats

Figure 3: Concentration of testosterone in blood serum of rats

Figure 4: Changes in levels of blood cells in peripheral blood of rats

## PAPERS:

P1234(28/90)\* Potapov PP.

*Activity of certain oxidative enzymes and transaminase in the liver of rats during recovery after hypokinesia up to 30 days in duration.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1):20-22; 1990.

[16 references; 1 in English]

Enzymology, Oxidative Enzymes, Transaminase, Liver

Rats

Hypokinesia, Immobilization Cages

**Abstract:** This experiment investigated the activity of pyruvate dehydrogenase (PDH),  $\alpha$ -ketoglutarate dehydrogenase (KGDH), succinate dehydrogenase (SDH), glutamate dehydrogenase (GDH), and alanine (ALT) and aspartate aminotransferase (AST) in the livers of rats during readaptation after a period of hypokinesia lasting 15 and 30 days. Subjects were 93 white rats, 13 of which were controls. The remainder were housed in individual immobilization cages for either 14 (group 1) or 30 (group 2) days. After this treatment 5 and 6 rats from groups 1 and 2, respectively, were sacrificed. The remainder were housed in group cages. One animal from each group was sacrificed daily for a total of 20 days in group 1 and 24 days in group 2. Measured parameters were processed using the moving average method (smoothing of 5 points). Statistical significance was determined using the Wilcoxon-Mann-Whitney test. Activity of cytoplasmic transaminase during and after 15 days of hypokinesia was measured in a separate study. All rats were sacrificed by decapitation. Mitochondria were isolated using differential centrifugation at 0-4°C, and the mitochondrial fraction was solubilized in a medium containing 0.2% Triton X-100. Activity of GDH was estimated on the basis of formation of the reduced form of pyronucleotides, activity of SDH, KGDH, and PDH from reaction with dichlorophenolindophenol as the electron acceptor. ALT and AST activity were measured separately in the mitochondrial and cytoplasmic fractions of the liver. Enzyme activity was expressed in nmoles/mg protein/minute. Protein was measured using Lowry's method.

On day 15 of hypokinesia, activity of SDH and KGDH was normal, activity of PDH was depressed, and activity of GDH and the transaminases was elevated. On day 30 of treatment SDH, GDH, and to a lesser extent KGDH activity was elevated. Activity of both transaminases was elevated in the cytoplasm, but only ALT activity was elevated in the mitochondria. During readaptation after 15 days of hypokinesia, activity of oxidative Krebs cycle enzymes was unaltered, GDH activity normalized on day 19, and activity of PDH was normal initially and then elevated between days 9 and 13. Activity of transaminases during the initial recovery period was even higher than it had been at treatment termination, normalizing on days 12-16. During early readaptation after 30 days of hypokinesia, SDH and KGDH activity was somewhat lower than during hypokinesia, but remained in the range of control values. At the end of week 3 of recovery, activity of these enzymes and of PDH increased significantly. Activity of GDH remained elevated until day 15 of recovery. Changes in cytoplasmic transaminases were less marked than in group 1 animals. Activity of mitochondrial ALT and AST after 30 days of hypokinesia was stable initially and then increased to a statistically significant extent, peaking on day 13.

The authors argue that although the activity of most of the enzymes studied was within normal limits, this should not necessarily be considered as a positive phenomenon, since their levels might not be sufficient to support increased energy expenditure after hypokinesia. Increase in activity of cytoplasmic and mitochondrial transaminases and also GDH during and after hypokinesia suggest activation of protein metabolism. In group 1 animals, increased PDH activity during readaptation coincided temporally with normalization of transaminase activity



## ENZYMOLGY

and decreased liver glycogen. The simultaneous activation of PDH supports rapid oxidation of pyruvate from glucose necessary to support energy expenditure. After 30 days of treatment, transamination and deamination processes normalize and are not accompanied by increased breakdown of carbohydrates as demonstrated by the stable level of liver glycogen.

Increased breakdown of proteins is one of the most important adverse effects of hypokinesia. For this reason functional readaptation after hypokinesia is associated with normalization of protein metabolism. Thus existing data do not indicate optimal metabolism in the liver during early recovery after hypokinesia. The utilization of amino acids for excess synthesis of carbohydrates, may substantially limit substrate support of protein synthesis and thus impede readaptation.

Figure 1: Activity of oxidative enzymes in the mitochondria and transaminases in the liver of rats during the recovery period after a 15-day period of hypokinesia

Figure 2: Activity of oxidative enzymes in the mitochondria and transaminases in the liver of rats during the recovery period after a 30-day period of hypokinesia

## EQUIPMENT AND INSTRUMENTATION

### PAPER:

P1244(28/90)\* Demina GN, Kirichenko GI.

*Algorithm for automatic recognition of base points on an impedance plethysmogram.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1):44-47; 1990.

[8 references; none in English]

Cardiovascular and Respiratory Systems

Humans

Equipment and Instrumentation, Impedance Plethysmography, Base Points

**Abstract:** This paper presents original algorithms for recognizing the base points in nondifferentiated impedance plethysmograms. The algorithms take into account the principles of distribution of base points along the temporal axis as a function of type of plethysmogram and state of the organ. The algorithms were tested on impedance plethysmograms of the brain, liver, chest, and limbs.

**Table:** Logical rules for recognizing base points on an impedance plethysmogram of the brain

**Figure 1:** Base points on an impedance plethysmogram

**Figure 2:** Base points on typical impedance plethysmograms of the brain recognized using the algorithm

## PAPER:

P1280(28/90)\*\*Berlin AA.

***The functional status of the skin in humans inhabiting pressurized environments of limited size.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):51-54; 1990.

[9 references; none in English]

Skin, Protective Function, Desquamation

Humans, Males, Females

Habitability and Environment Effects, Pressurized Environment, Personal Hygiene

**Abstract:** Studies were performed on healthy subjects of both sexes, aged 19-65. Some and possibly all experiments took place under conditions of 90 days' confinement in a pressurized environment (size and number of people at a time not specified). In a preliminary study apparently not using a pressurized environment, desquamation was studied in the same 19 subjects when they took daily showers using their accustomed cleansing agents and without daily showers (not specified whether any showers taken by latter group, not specified how long the experiment lasted, or when measurements were made). Daily showers were concluded to virtually double desquamation on the hand and in the vicinity of the collar bone and to increase it by 25% on the calf.

Rate of desquamation was also studied in two 90-day experiments in hermetically sealed environments. Desquamation was studied on the forearm, subclavian area, back and calf. Subjects showered once every 7 days. Subjects were compared to others with the same shower rate not confined in a sealed environment. Other skin characteristics studied included amount of skin oil and exfoliated skin. Under these conditions desquamation decreased significantly in all subjects (by more than a factor of 2 in some) by the end of their confinement. By the end of the 90-day confinement lipids and scaling had increased in all subjects, while skin moisture decreased. Skin pH increased during confinement in the pressurized environment by almost a unit, while eH decreased.

The author concludes that changes in the skin during confinement in a pressurized environment lead to a decrease in the protective function of the skin and create conditions favorable to the multiplication of transient microflora. These changes might decrease the role of antagonistic relations between resident autoflora and exogenous microflora from the environment, including pathogenic species.

Table 1: Rate of desquamation with and without showers

Table 2: Rate of desquamation during 90-day experiments involving confinement in a pressurized environment

Table 3: Change in skin moisture, lipid level, and scaling epidermis on the skin of subjects undergoing 90 days of confinement in a pressurized environment

Table 4: Value of pH and eH of the skin of subjects participating in a 90-day experiment

## PAPERS:

P1257(28/90) Gubin AT, Sakovich VA, Shafirkin AV.

***The development of radiation damage in the hemopoietic system.***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 904-905.

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Hematology, Hemopoietic System

Mathematical Modeling

Radiobiology, Radiation Damage

Abstract: The authors previously proposed a mathematical model for describing changes in the number of hemopoietic colony-forming stem cells during prolonged exposure to radiation varying in dose rate. The differential equation for change in the quantity of stem cells in time used in this model is:

$$\frac{dq}{dt} = \delta qS - \beta(1-q)S - \frac{D^0}{D_0} S$$

where  $\delta$  is the specific rate of cell reproduction,  $\beta$  is the specific rate of their differentiation, and  $D^0/D_0$  is the specific rate of their inactivation in prolonged irradiation with dose rate  $D^0$ . It is assumed that cell differentiation occurs from a state of rest,  $G_0$ , and the probability of being in the mitotic cycle is a function of total number of stem cells,  $\hat{q} = 1 - aS$ . The solution of this equation is the log curve:

$$\frac{S}{S^*} = \frac{1}{1 - \frac{D^0}{D_0\delta}} + \left[ 1 - \frac{1}{1 - \frac{D^0}{D_0\delta}} \right] e^{-\left( \delta - \frac{D^0}{D_0} \right) t}$$

When this model is used, good correspondence to experimental data can be attained only by introducing a relatively strong association between rate of multiplication of stem cells and dose rate. To overcome this failing the authors tested several more complex expressions relating the multiplication rate of stem cells to their number. It was proposed that rate of multiplication was inhibited with increases in the number of stem cells  $S(t)$  and total number of bone marrow cells  $M(t)$  in accordance with the law:

$$q = 1 - a \frac{\ln S}{\ln S^*} - b \frac{\ln M}{\ln M^*}$$

where  $S^*$  and  $M^*$  are the normal cell levels. The corresponding differential equation for change in the number of stem cells and total quantity of bone marrow cells has the form:

$$\frac{dS}{dt} = S \left\{ \delta \left[ 1 - a \frac{\ln S}{\ln S^*} - b \frac{\ln M}{\ln M^*} - \frac{\beta}{\delta} \left( a \frac{\ln S}{\ln S^*} + b \frac{\ln M}{\ln M^*} \right) \right] - \frac{D^0}{D_0} \right\}$$

$$\frac{dM}{dt} = \beta \delta \left[ a \frac{\ln S}{\ln S^*} + b \frac{\ln M}{\ln M^*} \right] K - \frac{M}{T}$$

where K is the total coefficient of multiplication of stem cells in bone marrow in the process of differentiation, and T is the life-span of bone marrow cells. Using a condition of equilibrium for the initial state of the system  $1 - (a+b) = \frac{\beta}{\delta}(a+b)$  and assuming that

$v = \frac{a}{a+b}$ , these equations can be rewritten in a more convenient form:

$$\frac{d \left( \frac{S}{S^*} \right)}{dt} = \frac{S}{S^*} \left\{ \delta \left[ 1 - v \frac{\ln S}{\ln S^*} - (1-v) \frac{\ln M}{\ln M^*} \right] - \frac{D^0}{D_0} \right\}$$

$$\frac{d \left( \frac{M}{M^*} \right)}{dt} = \frac{S}{S^*} \left[ v \frac{\ln S}{\ln S^*} + (1-v) \frac{\ln M}{\ln M^*} \right] \frac{K}{K^*} \frac{1}{T} - \frac{M}{M^*} \frac{1}{T}$$

When the relative number of cells decreases as a result of radiation, compensatory processes develop in the body that serve to achieve a new steady state leading to intensified proliferative processes in the regenerating systems of the body and to an increase in the coefficient of multiplication of cells compared to the norm. It was assumed that the ratio of the coefficient of multiplication in irradiation to that in the norm is determined by the relationship

$$\frac{K}{K^*} = \left( 1 + \ln \frac{M^*}{M} \right)$$

In the general case these equations may be solved numerically. For equilibrium concentrations of cells  $\frac{S_e}{S^*}, \frac{M_e}{M^*}$  established in irradiation with relatively low dose rates, there are relatively simple solutions, as follows:

$$\frac{M_e}{M^*} = \frac{S_e}{S^*} \left( 1 + \ln \frac{M^*}{M_e} \right) \left( 1 - \frac{D^0}{D_0 \delta} \right); \quad \frac{M_e}{M^*} = \exp \left\{ - \frac{D^0 \ln M}{D_0 \delta} \right\} \quad \text{when } v \ll b$$

Work utilizing analysis of experimental data for a number of animal species has demonstrated that the relative concentration of bone marrow cells corresponding to the new equilibrium level actually does decrease exponentially as a function of dose rate. The other relationship presented above was also confirmed. The model-based description of the dynamics of the relative quantity of bone marrow cells and the concentrations of neutrophils in blood in various animals after acute irradiation was also empirically confirmed.

P1259(28/90 Smirnova OA, Zukhbaya TM.

***The stimulating effect of chronic irradiation with small dose rates on lymphopoiesis and granulocytopoiesis. (Results of mathematical modeling and experimental data.)***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 923-924.

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Hematology, Granulocytopoiesis, Lymphocytopoiesis, Chalone Mechanism

Mathematical Modeling, Mammals, Rats

Irradiation, Chronic, Low Dose

**Abstract:** Mathematical models were developed describing the dynamics of lymphopoiesis and granulocytopoiesis in mammals exposed to prolonged irradiation. They were based on the chalone mechanism for regulating rate of blast cell multiplication in bone marrow and had the form of a system of nonlinear differential equations. Dose rate of radiation was represented as a variable in the equation, and the constants represented meaningful concepts in hematology and radiobiology.

The results of the modeling were compared with experimental data obtained in research on dynamics of hemopoiesis in rats exposed to chronic irradiation at a dose rate of  $N=0.1$  Gy/day up to  $N = 4$  Gy/day. Qualitative and quantitative agreement was obtained. Thus, the models reproduce the capacity of the lymphopoietic and granulocytopoietic systems to "adapt" to prolonged irradiation at small and moderate dose rates. New dynamic equilibria are established in the systems, characterized by differences from the norm in concentrations of lymphocytes and granulocytes in peripheral blood and their precursors in bone marrow. The model also simulates the irreversible exhaustion of these types of hemopoietic cells in chronic irradiation at high dose rates.

The models describe the stable increases above the norm in concentrations of lymphoid and myeloid cells in bone marrow and granulocytes in peripheral blood that occurred in experiments on rats undergoing prolonged irradiation with low dose rates of  $N = 0.1$  Gy/day.

The model of lymphopoiesis was used to simulate experiments on acute irradiation of rats which had or had not been previously exposed to chronic irradiation at a dose rate of  $N=0.1$  Gy/day. Computations showed that the processes of recovery are more intense and rapid in previously irradiated animals. This prediction of the model agrees with data concerning increased autorecuperative capacity of tissue in mammals (rats, mice, humans) exposed to an increased radiation background for a long period of time.

P1251(28/90)\* Rachkov AG, Rachkova LG, Daniyarov SB.

***Hemostasis in prolonged exposure to  $\gamma$ -irradiation at high altitudes.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 55-57.

[10 references; none in English]

Hematology, Hemostasis

Dogs

Radiobiology,  $\gamma$ -Irradiation, High Altitudes

**Abstract:** The goal of this work was to study hemostasis in dogs exposed to prolonged  $\gamma$ -irradiation on day 3 of adaptation to high altitude conditions. Subjects were 20 outbred dogs. A cannula was inserted in an artery of the leg to obtain blood. Blood was taken before irradiation and on day 10 of radiation sickness and immediately centrifuged for 10 minutes at 1500 rev/min to obtain plasma. Blood was also subjected to electrocoagulography. Effects of irradiation on hemostasis were studied in 10 dogs at low altitudes and in 10 others at an altitude of 3200 m above sea level, to which they were exposed for 3 days and then baseline parameters obtained. Animals were irradiated at a dose of 2.5 Gy with dose rate of 0.12 Gy/hour. Groups of four animals were irradiated simultaneously. Animals were always studied on day 10 after irradiation. No animals died during this period in either condition.

Results are interpreted as indicating that a thrombohemorrhagic syndrome develops, along with disruption of thrombocytopoiesis, in pathogenesis of hypocoagulation in irradiated animals at normal altitudes. The development of intravascular clotting of blood on day 3 of exposure to high altitudes leads to development of signs of secondary hypocoagulation, which attenuates development of postirradiation thrombohemorrhagic (thrombopathic) syndrome at high altitudes.

Table 1: The effect of prolonged  $\gamma$ -irradiation on hemostasis at low altitudes

Table 2: The effect of prolonged  $\gamma$ -irradiation on hemostasis at high altitudes

P1285(28/90)\*\* Pak GD, Sverchkova VS, Danilevskaya TN.

*The hemostasis system under conditions of various levels of hypoxic hypoxia.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 4-9;1990.

[62 references; 18 in English]

Hematology, Hemostasis

Literature Review

Hypoxia, Hypoxic

**Abstract:** This article reviews the literature (mainly Soviet) on the effects of hypoxic hypoxia on hemostasis. The preponderance of the works suggest that hypoxia, no matter how created, tends to activate blood clotting. Literature shows that milder forms of hypoxic treatments do not affect hemostatic parameters to a significant extent. Moderate hypoxia appears to lead to moderate predominance of coagulative activity, while severe hypoxia leads to severe hypercoagulation. However, other data contradict this simple conclusion. Part of the reason for the contradiction may be a failure to take into account individual differences in sensitivity, compensatory mechanisms, etc., as well as objective levels of oxygen. It is suggested that hypoxemia, and not hypoxia per se, acts as the triggering factor in hemostatic disruption. Under conditions of hypoxia there is a strong correlation between hypercoagulation and decreased blood pH and also a sharp increase in number of thrombi in the lungs and brain vasculature when pH decreases from 7.2 to 6.9. It is concluded that flexibility of coagulative properties of the blood in hypoxia is strongly affected by changes in  $pO_2$ ,  $pCO_2$ , and pH of blood. Hypoxia has been shown to attenuate the effects of adrenalin on increasing clotting and fibrinolytic times. Since there appeared to be a link between changes in the respiratory and coagulative properties of blood, it was suggested that, because  $CO_2$  increases oxygenation of blood by increasing pulmonary ventilation, a moderate amount of  $CO_2$ , added to a hypoxic breathing medium might prevent hypercoagulation. This was indeed the case for addition of 5%  $CO_2$  to a hypoxic mixture that alone produced hypercoagulation. However, addition of the same level of  $CO_2$  to a normoxic medium increased blood coagulation. Disruption of acid-base balance is also important in hypercoagulative response to hypoxia, and this too can be corrected when the ratio of  $O_2$  and  $CO_2$  is optimum in breathing medium and blood.

Figure 1: Silicon time for plasma as a function of  $p_aO_2$ ,

Figure 2: Coagulogram under conditions of hypoxia and hypoxia with hypercapnia

Figure 3: Silicon time and fibrinolytic activity of plasma before and after introduction of adrenalin under conditions of hypoxia and hypoxia with hypercapnia



## PAPER:

P1248(28/90)\* Yegorov SV, Kostrina VG.

*Evaluation of operator's readiness to act in an emergency.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 52-53.

[4 references; none in English]

Human Performance, Evaluation, Emergency Response

Human, Operator

Monotony

**Abstract:** This study investigated changes in the structure of responses to an emergency signal under simulated conditions of monotony. The operator's task was to monitor parameters of a dynamic object regulated automatically and report to the experimenter when parameters exceeded acceptable limits. Approximately every 25-30 minutes the operator was to respond by using a knob to change the mode of operation of the device based on the readings of three instruments. Subjects were 10 apparently healthy operators who had been trained in the use of this device. Electroencephalograms were recorded and time parameters and control movements were monitored to allow computation of the "coefficient of working set," ratio of time required to respond under normal conditions and under monotonous conditions. The response interval was divided into two parts and a coefficient computed for each. The first part, called the transition period, was the time between presentation of the emergency signal and beginning of the response. The second portion, called the recognition period, was the time between the operator's first movement and the actual response, which was based on comparison of data from three instruments followed by selection of an appropriate action. Results suggest that the transitional period, representing the time to initiate action and intervene in the control process, was more subject to the negative effects of monotony than the period required to recognize the situation, which involved analysis of the situation and decision making, and was relatively resistant to the effects of monotony.

Figure 1: Diagram of analyzed temporal characteristics of the structure of operator response to emergency signal

Figure 2: Comparative evaluation of coefficient of working set for total response time, transition period, and time to recognize situation

P1269(28/90)\*\*Ivanov VI, Ivanov VI.

*Techniques and means for optimizing functional status of flight school cadets during preflight activity.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):18-21; 1990.

[37 references; none in English]

Human Performance, Optimization, Functional Status

Humans, Flight School Cadets

Preflight Training, Exercise, Feedback

**Abstract:** The goal of this work was to develop means of optimizing the psychophysiological status of cadets in flight school prior to their beginning actual flights. Physical education courses were taken as the model for course material. The major group of subjects included 61 people attending physical training classes in an airfield camp. A set of cyclic exercises was developed emphasizing aerobic physical training. Exercise was graded at a rate attainable by the cadets. Pulse rate reached a mean of 120-148 per minute with motor exertion no greater than 65%. The set of exercises -- cross-country running and swimming -- was performed twice a week. The water in which cadets swam was controlled to create a feeling of alertness and freedom. Training was provided the cadets in monitoring and controlling their state using biofeedback. The cadets were told the values of the parameters registered by the instrument before physical training. When a deviation was noted after training, the cadets themselves regulated their level of emotional arousal in the required direction. The control group contained 26 cadets who engaged in physical training without the special procedures. Under preflight conditions, cardiovascular function was evaluated on the basis of heart rate, systolic and diastolic blood pressure, autonomic index computed by a formula, inspiratory breath-holding time, color vision, emotional perception of color tones, critical flicker fusion sensitivity (index of visual sensitivity), and problem solving time. After the flight, subjects filled out a questionnaire concerning subjective evaluation of the experimental training on their state and performance. One month before the flights, baseline parameters were measured 3 times. During flights the parameters were measured twice: 8-10 minutes before start of independent flight and immediately after flight completion.

Signs of emotional stress were different in the experimental and control groups before and after the flight. The experimental cadets were less subject to the effects of preflight stress, as indicated by lower values of heart rate, bioelectric parameters, systolic blood pressure, and higher values for breath-holding time and flicker fusion frequency. Differences in all these parameters were statistically significant. Computation of the autonomic index indicated that the experimental subjects showed less activation of the sympathetic nervous system. In addition, students performing best on flights showed less sympathetic activation. Control subjects showed diminished capacity to distinguish blue and gray before the flight, but experimental subjects did not. In addition, critical flicker fusion frequency was diminished for red light in the control group. Mental performance as indexed by speed at problem-solving tasks decreased significantly postflight in the control, but not the experimental group. Questionnaire results confirmed that the self-regulation training improved psychological state in the experimental group. The authors conclude that their treatment had beneficial effects on psychological aspects of flight performance.

## HUMAN PERFORMANCE

P1283(28/90)\*\* Matseychik Ya, Terelyak Ya (Poland).

*The effect of relaxation on perceptual/motor performance of humans.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 62;1990.

[6 references; 3 in English]

Human Performance, Perception, Perceptual/Motor Performance

Humans

Autogenic Training, Relaxation

**Abstract:** This work evaluated the effect of autogenic relaxation training on perceptual/motor performance. Training involved exercises in muscle tension and relaxation, then development of the ability to sense the weight and temperature of the muscles, followed by breathing exercises and regulation of cardiac activity. Perceptual motor performance was assessed by a series of tests of fine motor coordination, manual dexterity, sensorimotor coordination, perceptual speed, attention, and thinking. In addition, anxiety level was assessed before and after the training procedure. Level of relaxation was monitored on the basis of heart rate and blood pressure. A total of 13 volunteers of both sexes, aged 20-35, participated. Subjects were students and scientists who had complained of various psychogenic ailments. Participants had utilized relaxation training for periods ranging from 2 months to 2 years.

After relaxation, improvements were noted in certain tests, but not in others. Relaxation was associated with decreased anxiety, heart rate and blood pressure.

P1260(28/90) Smirnova OA.

***Humoral immunity in irradiated mammals (Mathematical Model).***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 924-925.

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Immunology, Humoral Immunity  
Mathematical Modeling, Mammals  
Radiobiology, Irradiation

**Abstract:** A mathematical model was developed of the combined effects of ionizing radiation and antigen stimulation on the mammalian system of humoral immunity. This model is based on the clonal-selection theory of Burnet, ideas concerning the interaction of antigen molecules and receptors on the surface of immunocompetent cells, hypotheses about the mechanisms underlying radiation damage and recovery of the lymphopoiesis system, and experimental data on the radiation sensitivity of cells.

The model is implemented as a system of differential equations for the concentration of antigens, antibodies, damaged and undamaged immunocompetent cells and their precursors in bone marrow.

The model describes the dynamics of accumulation of antibody-forming cells and antibodies during the initial immune response of the non-irradiated organism to T-dependent antigens. The data generated by the model agree qualitatively with experimental data.

The model reproduces the major regularities in postradiation dynamics of lymphopoiesis in nonimmunized animals. Quantitative agreement was obtained between the model-generated data and experimental data concerning processes of damage and recovery of bone marrow and lymphoid tissues.

The model simulates damage to the immune system after combined exposure to ionizing radiation and immunization. It was demonstrated that the maximal concentrations of antibody-forming cells and antibodies decrease with radiation dose when there is a constant time interval between irradiation and antigen stimulation.

The model reflects the processes of recovery of the immune system. As the interval between irradiation and immunization increases, maximum concentrations of antibody-forming cells and antibodies increase, approaching the value for the nonirradiated organism. The model may be used to predict dynamics of the immune response in irradiated mammals.

### PAPERS:

P1242(28/90)\* Kozyarin IP, Suk VG, Maslenko AA, Khil'ko OK.

*Hygienic evaluation of oxygen produced by a system containing a solid polymer electrolyte.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina

24(1): 36-40; 1990.

[20 references; none in English.]

Evaluation, Oxygen

Rats, Humans

Life Support System, Solid Polymer Electrolyte

**Abstract:** Oxygen for use in pressurized environments in space can be generated through the electrolytic decomposition of water. This is a relatively simple way to obtain oxygen, but the resulting gas product has not been sufficiently analyzed from the standpoint of its effects on living organisms. This study analyzed the biological effects of oxygen so produced from three samples of water containing various inorganic and organic chemical substances. The third sample consisted of distilled water conforming to USSR state standards. Samples one and two contained various amounts of added ammonia, urea, chlorides, carbon monoxide, magnesium, nickel, zinc, calcium, iron, and potassium. Ion-exchange polymer material served as the electrolyte in the oxygen-generating system. The study measured the proportion of oxygen resulting from electrolysis, its isotopic composition, the hygienic characteristics of the gases, and the presence of inorganic and organic contaminants (CO, CO<sub>2</sub>, O<sub>3</sub>, water vapor, gaseous acids and bases, and alkali). Samples 1 and 2 were further studied with regard to specific electrical conductance, pH, concentration of ammonium nitrate, urea, chlorides, bichromate oxidizability, and presence of trace elements. Water samples were studied immediately after production and also 6, 12, 18 and 24 hours after the oxygen producing apparatus had begun to operate. Resulting oxygen was studied at times 1 and 24 hours after the apparatus had begun to operate. The odor of the resulting oxygen was rated on a 5 point scale by volunteers who breathed it through a mask for 2-3 minutes. Safety of the oxygen as a breathing atmosphere was tested with 60 white outbred rats, half of which breathed the oxygen produced by the system to which pharmaceutical nitrogen had been added, while the others breathed air. Animals in the first group spent 1 month in a closed environment in which they breathed oxygen produced electrolytically from distilled water. Animals of group 2 were exposed to oxygen produced from sample 1 around the clock for 2 months. Animals in group 3 were exposed to oxygen from sample 2 round the clock for 2 days. Parameters studied in the animals included body weight, weight and morphology of visceral organs, cardiovascular parameters, static work capacity, and red blood count. In subsequent experiments, cardiorespiratory functions were measured in human volunteers who breathed oxygen produced from the water samples (mixed with nitrogen) for 30 minutes.

Study of the properties of the electrolytically generated oxygen showed that concentration of oxygen was over 99% in all three samples and that duration of electrolysis did not affect level of oxygen. The oxygen produced had no odor, and contained no carbon monoxide, alkali, or gaseous acids or bases, ozone or other oxidative gases. The gas produced in all three cases met USSR state standards. No effects were noted on the experimental animals. Human subjects showed no regular significant effects of breathing the electrolytically produced oxygen.

Table 1: Physical-chemical parameters of water samples subjected to electrolysis

## LIFE SUPPORT SYSTEMS

Table 2: Parameters of electrolytically produced oxygen obtained from water in a system with a solid polymer electrolyte

Table 3: Certain parameters of the functional state of animals at the end of an experiment involving breathing an atmosphere containing electrolytically produced oxygen and gaseous nitrogen

Table 4: The effect of a gas containing electrolytically produced oxygen and nitrogen on human subjects

### PAPERS:

P1258(28/90) Smirnova OA.

***Dynamics of critical systems and radiation death of mammals (Mathematical modeling).***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 922-923.

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Radiobiology, Radiation Death, Hematology, Hemopoiesis; Gastrointestinal System, Intestinal Follicles

Mammals

Mathematical Modeling

**Abstract:** Mathematical models have been developed for various types of hemopoiesis in animals undergoing acute and chronic irradiation. They are based on computation of the chalone mechanism for regulating rate of division of blast cells in bone marrow and have the form of a system of nonlinear differential equations, with variables for concentrations of mature blood cells and their precursors in bone marrow. The dose rate and total dose of radiation enter the model as parameters. The models reproduce the experimentally observed dynamics of hemopoiesis of unirradiated mammals, dynamics of radiation damage, and recovery of the pool of cells in bone marrow and peripheral blood after acute irradiation, and the exhaustion of these pools during long-term chronic exposure to radiation.

Mathematical models have been developed to describe dynamics of cell density in the epithelium of the small intestine in small laboratory animals under conditions of acute and chronic irradiation. They are based on the chalone mechanism for regulating the rate of multiplication of intestinal follicles and consist of a system of nonlinear differential equations, in which the concentration of follicles and villi serve as variables. The models reproduce the dynamics of radiation damage and recovery of the follicle-villi system after acute irradiation and also describe the exhaustion of this system after chronic irradiation.

A mathematical model has been developed to describe dynamics of death rate in mammals exposed to acute and chronic ionizing radiation. These associate statistical biometric functions — death rate, probability density, and probable life-span — with statistical and kinetic properties of physiological systems. All model constants have a real physical meaning and may be estimated from experimental data. As an example, the author considers intervals of dose rate and radiation dose, for which hemopoiesis (thrombopoiesis) and the follicle-villi system are critical. The cell density of these systems was computed using appropriate mathematical models. The results of modeling and experimental data on death rate and mean life-span shortening of small laboratory animals exposed to chronic and acute radiation agreed qualitatively and in a number of instances quantitatively as well.

## MATHEMATICAL MODELING

P1272(28/90)\*\* Grigoryan SS, Simonov LG, Tsaturyan AK.

*A mathematical model of intracranial blood and cerebrospinal fluid circulation system as applied to the study of the effects of extreme conditions.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 25-29; 1990.

[27 references; 14 in English]

Cardiovascular and Respiratory Systems, Circulation, Blood, Neurophysiology, Body Fluids,  
Cerebrospinal Fluid

Mathematical Modeling, Humans

Extreme Conditions, Tilt Tests, Provocative Tests

**Abstract:** This work attempted to develop a mathematical model of intracranial circulation of blood and cerebrospinal fluid, accounting for effects of factors inducing fluid shifts and redistribution. To create such a model it was necessary to have a theoretical description of the biophysical characteristics of the intracranial circulation system that reflected viscous and elastic properties of system components, and also data from clinical and physiological experimental studies. This model attempted to represent the interrelationship between the cerebrospinal fluid, arterial and venous system, and also to provide the capacity to model changes of the state of blood and cerebrospinal fluid circulation under the influence of disruptive factors. The model was used to simulate the effects of tilt tests and other provocative tests that lead to fluid redistribution and changes in relationships among volumes and pressure on circulation of blood and cerebrospinal fluid. The data generated by the model was consistent with empirical data and the model was judged to be adequate.

**Figure 1:** Reactions of a mathematical model of blood and cerebrospinal fluid circulation to decrease and subsequent increase in fluid in the cerebrospinal system

**Figure 2:** Relationship of range of pulsations in cerebrospinal fluid pressure to the mean pressure

**Figure 3:** Reactions of a mathematical model to rapid infusion of liquid into the cerebrospinal fluid system

**Figure 4:** Pressure of cerebrospinal fluid as a function of volume of fluid introduced into the system and volume of cerebrospinal fluid in the skull for the "basic" variant of the model



## MUSCULOSKELETAL SYSTEM

### PAPERS:

P1273(28/90)\*\* Tatarinov AM, Dubonos SL, Yanson KhA, Oganov VS, Dzenis VV, Rakhmanov AS.

***Ultrasound diagnosis of the status of the tibia in humans undergoing a 370-day period of head-down tilt.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 29-31.

[15 references; 6 in English]

Musculoskeletal System, Tibia Bone, Ultrasound

Humans

Hypokinesia With Head-Down Tilt, 370-Day, Prophylactic Countermeasures, Exercise

**Abstract:** This study used ultrasound to evaluate bone changes during long-term hypokinesia and also to compare effectiveness of prophylactic measures. Measurements were made on 20 bands along the length of the tibia, from the direction of the medial surface at a distance of 100 mm from the crest of the anterior edge of the bone. Error of measurement was approximately 2%. Parameters selected as indicative of bone status included: mean speed of ultrasound through all 20 bands (C), mean speed of ultrasound in the diaphysis (C $\delta$ ), and gradient of decrease of ultrasound speed in the distal half of the bone ( $\Delta$ C). On the basis of previous measurements it was assumed that overall mean speed would be related to concentration of minerals, while mean speed in the diaphysis and gradient of decrease would reflect the biomechanical properties of bone adaptation to hypokinesia. Measurements were performed during a baseline period, 60 and 180 days after the beginning of the hypokinesia period [tilt not specified, but known from other papers to be -5°], and subsequently every 2 months, as well as 2 and 12 months after treatment termination. Subjects were 9 volunteers, aged 27 to 41, of whom 5 (group A) engaged in physical exercise as a countermeasure throughout the treatment period, and 4 (group B) began exercise during month 5 of bedrest.

The majority of subjects displayed reliable changes in ultrasound parameters during treatment. A stable decrease in C $\delta$  (by 6-12%) occurred in 3 subjects throughout the bedrest period. In 2 subjects, changes in this parameter were cyclical, and in the remaining 4, diaphysis and overall ultrasound speed remained stable.  $\Delta$ C, which reflects acoustic inhomogeneity of bone, decreased during hypokinesia in 8 subjects (from 0.28 to 0.03 km/sec.). In only 1 subject (in group A) did acoustic parameters increase. It is concluded that individual differences in acoustic parameters are relatively significant. When mean group values of parameters were studied it was evident that decreases occurred only during the first half of the treatment period. During days 240-300 stabilization and even recovery occurred, evidently associated with the prophylactic measures. Decrease in C $\delta$  during the first half of the period was more extreme in group B, which did not start to exercise until month 5. In both groups, the most pronounced changes occurred in the medial and proximal portions of the diaphysis. Such changes suggest relative adaptive redistribution of elastic properties throughout the bone in response to altered magnitude and vector of loading. Analysis of the recovery period shows that the most labile parameters ( $\Delta$ C and C $\delta$ ) normalize at different rates, but after 1 year do not differ from baseline.

Comparison of ultrasound and earlier data using  $\gamma$ -photon absorptiometry suggests that ultrasound provides information about bone changes earlier in their development. Differences between groups were more pronounced with ultrasound measurements than with densitometry. No correlations were noted between changes in mineral density and changes in ultrasound measurements.

## MUSCULOSKELETAL SYSTEM

Table: Mean acoustic parameters of the state of the tibia bone during a 370-day period of hypokinesia with head-down tilt and during the recovery period

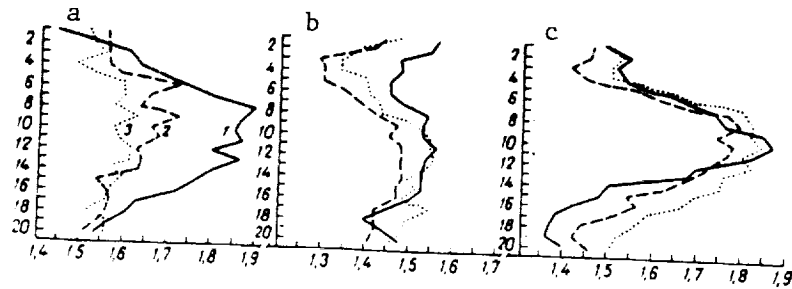


Figure 1: Acoustic profile of the human tibia bone in the norm (solid line) and during hypokinesia (broken line - 60 days, dotted line - 360 days)

Abscissa: ultrasound speed, measured along the medial surface of the tibia (in km/sec); ordinate: measurement bands from the proximal (top) to distal portion of the bone. a, b, c - variant of change in the acoustic profile of various individuals

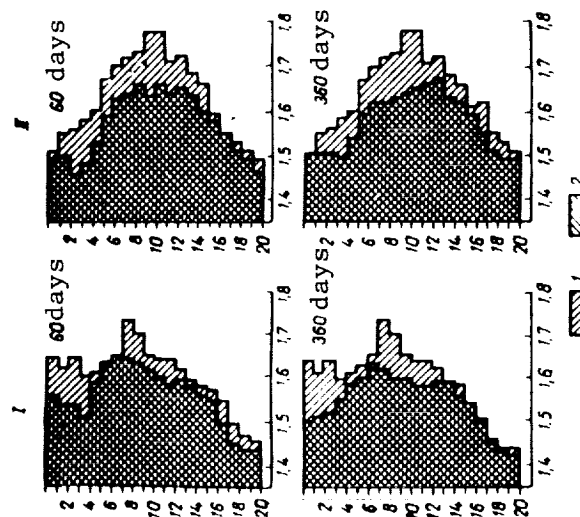


Figure 2: Mean group acoustic profile of the tibia bone in the norm (1) and in the process of hypokinesia (2)

I - group A, II - group B. Remaining symbols as in Figure 1.

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P1274(28/90)\*\* Morukov VB, Orlov OI, Belakovskiy MS, Kazeykin VS, Zaychik VYe, Shvets VN, Tumanova IYu.

***The effect of simulated weightlessness on calcium metabolism and state of bone tissue in experimental animals.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 31-34.

[25 references; 13 in English]

Musculoskeletal System, Bone; Metabolism, Calcium; Endocrinology

Rats, Male

Hypokinesia, Immobilization Cages; Hypodynamia, Tail Suspension

**Abstract:** A 40-day experiment was performed on male Wistar rats. Hypokinesia was created through rigid fixation of the animals in immobilization cages, and hypodynamia by tail suspension. Control animals were maintained under vivarium conditions. Animals in all groups ate an identical diet containing optimal minerals. After the experimental period terminated, the animals were sacrificed and bone tissue and blood extracted for further analysis. Concentration of total calcium in blood serum was measured titrimetrically and its ionized fraction using an ion-selective electrode. Concentration of phosphorus was measured spectrophotometrically. Hormonal levels (parathyroid hormone /PTH/, calcitonin /CT/ and corticosterone) were measured using standard test kits. Data obtained was used to compute coefficient of ionization of calcium in blood serum and the index of calcitropic hormones. Isolated femur bones were cleaned of muscle tissue and lyophilized. The length of the femur was measured with calipers. Bones were weighed in air and distilled water to determine the volume and density of whole bone and fragments. The neutron activation method was used on the head of the femur to find concentration of calcium, phosphorus, and magnesium. Coefficients of Ca/P and Ca/Mg were computed. The spongy tissue in the metaphysis of the tibia bones was subjected to morphometry using an ocular micrometer. The relative volume of the trabeculae was expressed as percentages. Strength of the femur was determined by a bend test and strength of the head of the tibia by a compression test. A loading diagram was used to compute the rigidity of the bone tissue sample. Analysis of variance was applied to the data.

Results are presented in Tables 1 and 2. The authors conclude that both hypokinesia and hypodynamia lead to changes in calcium-phosphorus homeostasis. The genesis of the observed changes in bone tissue status is considered to differ in the two cases. Limitation of overall motor activity induces inhibition of bone growth and development of osteoporosis. Decrease in static and dynamic gravitational loading on bone leads to decreased rate of periosteal bone formation and the beginning of internal reorganization of trabecular bone tissue. Thus to evaluate the effectiveness of pharmacological countermeasures in simulation experiments using animals, the authors consider it essential to use both cage-hypokinesia and suspension, since they model different components of the pathogenesis of possible disorders of bone tissue in weightlessness.

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Table 1: Bone parameters in experimental animals

Parameter	Control	Hypokinesia	Hypodynamia
Length, mm	36.9	35.1*	36.9
Weight, mg			
epiphysis	71.57	45.40*	53.60*
diaphysis	203.79	172.71*	167.36*
Volume, mm <sup>3</sup>			
epiphysis	27.2	25.7	23.7
diaphysis	117.6	73.3*	84.0*
Density, mg/mm <sup>3</sup>			
epiphysis	1.370	1.291*	1.343
diaphysis	1.735	1.705	1.733
Trabecular tissue volume, %	25.3	11.9*	10.5*
Weight-bearing capacity, kgf			
epiphysis	6.333	3.883*	4.560
diaphysis	10.65	9.355	7.143*
Rigidity, kgf/mm			
epiphysis	78.73	49.03*	52.20*
diaphysis	52.52	43.92*	35.02*
Mineral components, mg/g			
calcium	264.9	239.0	223.2*
phosphorus	176.9	159.7	159.9
magnesium	6.5	8.2	10.3
Ratios			
Ca/P	1.69	1.38	1.55
Ca/Mg	37.7	30.5	25.1*

Here and in Table 2, \* -  $p < 0.05$  compared to control

Table 2: Parameters of calcium homeostasis in experimental animals according to data from biochemical analysis of blood serum

Parameter	Control	Hypokinesia	Hypodynamia
Total calcium, mmole/l	2.58	2.32*	2.34*
Ionized calcium, mmole/l	1.07	1.15	1.13
Coefficient of calcium ionization, %	40.6	50.4*	48.7*
Phosphorus, mmole/l	2.97	2.79	2.54*
PYH, pg/ml	0.92	0.83	0.89
Calcitonin, pg/ml	17.7	12.8	12.5
Index of calcitropic hormones, %	5.45	4.91	4.67
Corticosterone, ng/ml	7.18	27.3*	68.2*

## MUSCULOSKELETAL SYSTEM

P1286(28/90) Stupakov GP, Volozhin.

*The skeletal system of experimental animals under conditions of weightlessness: The effects of space flight on the weight-bearing bones of rats: Restructuring of bone tissue.*

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость

[*The Skeletal System and Weightlessness*].

Volume 63 In series: Problemy Kosmicheskoy Biologii,

Leningrad: Nauka; 1989.

Pages: 49-61.

Musculoskeletal System, Weight-Bearing Bones, Femur, Tibia, Brachium

Rats

Space Flight, COSMOS-615, -782, -936, -1129

**Abstract:** Experiments were performed on a total of 218 Wistar rats, of which 64 underwent space flights of 18.5-22 days on COSMOS-615, -782, -936, and -1129. A control group consisted of 154 rats. Some were maintained under vivarium conditions and others in a mock-up of the satellite with all space flight conditions simulated except weightlessness (synchronous control). Before the flight animals had been selected on the basis of a number of clinical criteria. During the flight they were maintained in individual cages equipped with systems to supply food, water, illumination, and ventilation and dispose of waste. The illumination schedule provided a 12-hour day. Air temperature was generally maintained between 20-22°, and humidity fluctuated between 40-65 or 80-90%, depending on flight. Partial oxygen pressure was 145-210 mm Hg, and carbon dioxide pressure was between 1 and 14 mm Hg. The animals received a paste diet. The synchronous group was exposed to noise, vibration, radial acceleration and impact similar to conditions in the flight capsule at appropriate points in the experiment. Animals were sacrificed several hours after the experiment terminated or after a rehabilitation period lasting 6 and 25-29 hours. Bones studied were the femur, tibia, and brachium.

Different experiments used different bone material and studied different properties. Four experiments measured the biometric parameters of the bones, biophysical properties that reflect the density of the structural composition of bone substance and the extent of its mineralization, concentration of chemical elements in the mineral component (Ca, O), histological structure, mechanical properties, and nature of disturbances.

In rats, parameters indicative of the state of bone tissue depend on the age of the animals. For technical reasons, rats of the two control groups had to be sacrificed several days before the animals of the experimental group. Thus, direct intergroup comparison of parameters would be inappropriate. For this reason values depending on age were compared to a so-called extrapolative control, determined by extrapolation of each parameter for a control animal as appropriate to the point in time that animal was sacrificed.

Changes in the functional status of bone tissue may be assessed on the basis of a variety of indirect and direct indicators. The first set of parameters includes pattern of change of bone size and weight, physical density of bone structure or density of mineral substances in it, mineralization of the bone matrix, and also data from histological, morphometric and radiographic methods. Direct indicators include changes in synthesis and resorption, as reflected by rate parameters: rate of bone formation and maturation, rate of appositional and osteochondrous osteogenesis, and certain other parameters. Only a multivariate analysis of changes identified through the use of a number of methods can give a valid picture of the status of bone tissue in microgravity.

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In space flight, increase in tibia and femur mass was slower than under control conditions (Figure 4), with discrepancies in the femur more severe, especially in the spongy substance (distal epiphysis and head). Normally, quantity of spongiosa is significantly greater in the femur than the tibia. The size of whole bones and fragments of the femur decreased less than their weight, suggesting increase in porosity.

Six days after reentry parameters of bone weight and size achieved control level, but the distal epiphysis and head of the bones did not recover fully until day 25-29 (Figure 5). Significant widening of the femoral diaphysis was observed due to depletion of the cortical layer of the periosteum (Figure 6). This suggests inhibition of osteogenesis. Greater decrements were observed in lateral measurements than in anteroposterior ones. As a result, bone shape altered, with cross-sections changing from elliptical to circular, as illustrated by the x-ray photographs in Figure 7.

Exposure to space flight was associated with decrease in density and mineral saturation of spongy structures, i.e., the distal epiphysis and head of the femur. In other words osteoporosis developed. Mineralization of the osteal substance was unchanged. No substantial changes were observed in the cortical layer of the diaphysis, but there was a slight tendency for decrease (Figure 9). Nor were differences found between the flight (COSMOS-1129) and control groups with respect to mineralization of microstructure of the diaphysis as revealed through radiography.

Data showed considerable inter-flight variability in loss of bone mass from spongy structures. Mineral saturation of the distal epiphysis decreased by 7.4 and 7.9% for animals flown on COSMOS-605 and -1129, respectively, while the analogous parameter was 21.1% for the COSMOS-936 flight. A similar discrepancy was observed in the head of the femur: 5.2% decrease on COSMOS-1129 and a 17.7% loss on COSMOS-936.

In control subjects, severity of spongy structure atrophy was found to be inversely correlated with mineral saturation (Figure 10). This provides a rationale for selecting individuals for long-term space flights who display high density of bony structure and thus are likely to have a low atrophy rate.

Osteoporosis was less pronounced and recovery faster in the head of the brachium than in the femur. While brachium recovery was complete after 6 days, signs of osteoporosis were still noted 25-29 days postflight in the femur. In rats, although both bones are weight-bearing, the brachium is less specialized and used for manipulative functions as well.

Histological photographs of the spongy structure of the distal metaphysis of the femur (Figure 12) in flight rats (COSMOS-605) reveal thinning of the spongiosa with high individual variability. Severe changes took the form of almost complete disappearance of both primary and secondary spongiosa. Extreme changes were not observed in the cortical layer close to the distal metaphysis.

Slides made from the medial region of the femoral diaphysis of flight (COSMOS-1129) rats revealed thinning and in certain areas disappearance of the external lamella. Osteoporosis was not observed within the cortical layer; however, its thinning suggests that change of restructuring rate involving inhibition of osteogenesis occurs under the influence of space flight factors. Experiments on COSMOS-782 confirm these findings and provide additional data on endochondral osteogenesis and restructuring of the spongy substance in proximal areas of the tibia. In flight rats the length of the primary spongiosa of this structure was reduced by more than 60%. Number of trabeculae per 1 mm width of bone and the proportion of primary spongiosa were depressed by 18 and 14%, respectively. The depth of spongiosa in the medullary cavity was diminished by a factor of 3. These changes were not accompanied by

## MUSCULOSKELETAL SYSTEM

changes in the length of the tibia bones or in the width of the proximal epiphysal layer or the mean width of trabeculae of the primary spongiosa. In flight rats trabeculae decreased significantly in length and only occasionally developed into secondary spongiosa tissue, which sometimes was almost completely absent. Such data can be explained by increased resorption in the slowed bone tissue restructuring phase.

American data on morphometry of compact bone showed no difference in maximal diameter of pores in bones of the flight group. Nor were changes found in the large Haversian canals, vascular canals, or in overall porosity. However, there was a slight but significant decrease in compact bone density.

The current authors found a slight relative increase in small canals in the femoral diaphysis of flight rats, which they suggest may result from intensification of resorption processes and the formation of new canals possibly due to resorption of the walls of the larger canals by the endosteum.

Thus, study of dynamics of bone weight and cross sections and histological data suggest inhibition of osteogenesis. Studies of bone porosity by physical (density, mineral saturation) and histological methods suggest activation of resorption, at least in the spongy structures.

Use of methods based on tetracycline markers permitted direct study of rate of formation of periosteal bone and rate of formation of the periosteal matrix, independently of mineralization characteristics for rats flown on COSMOS-782 (Holton, Baylink). Rates of bone and matrix formation were almost twice as high in the control as in the flight group. Subsequent experiments on later COSMOS flights had similar results. After a postflight recovery period of 29 days, rate of periosteal formation of bone tissue of the brachium and tibia had normalized almost completely.

The set of data discussed above supports the conclusion that in space flight all processes associated with bone growth — rate of synthesis of the organic matrix, and maturation of the bone associated with mineralization — are inhibited. Data obtained did not reveal indications of increased endosteal resorption. However, the authors argue that the flight data and other results support the following analysis. First, it has been demonstrated beyond a doubt that there is inhibition of bone formation in both the compact and spongy substance. Second, no signs of increased resorption were observed. Indeed, some evidence suggests actual slowing of resorption in compact bone. Third, investigation reveals severe thinning of bone substance in spongy structures with marked individual variability. It is argued that this is unlikely to result only from inhibited osteogenesis, especially since in some structures density of spongy structure was below initial density in experimental animals postflight. It is concluded that osteoporosis is likely to be a consequence of depressed osteogenesis as well as activated resorption (not actually demonstrated, but inferable from the general state of spongy tissue).

Since osteoclasts are associated with resorption, it is of interest to consider their number in spongy structures after space flight. The only study of this kind was performed by American researchers after the flight of COSMOS-1129. It was found that number of osteoclasts was virtually the same in control animals and those undergoing space flight.

An alternative mechanism for thinning of bone is perilacunar (osteocytic) osteolysis. Data supporting the occurrence of this process is provided by Yagodovskiy et al., who observed broadening of osteocyte lacunae and changes in surrounding bone tissue in rats flown in space. However, data are far from conclusive.

Mechanisms underlying inhibition of osteogenesis and decreases of skeletal mass of long bones in hypogravity are also not yet understood. One hypothesized mechanism is that decrease in

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mechanical loading leads to decreased osteoblast activity. However, data here are inconclusive as well.

The authors point out that it is difficult to extrapolate data on bones of rats, which grow throughout their lives, to effects on humans. And with this warning, they summarize the COSMOS bone data as follows. Histomorphometric analysis of critical bones of rats flown in space provides a basis for concluding that weightlessness gives rise to cessation, rather than depression, of bone formation. The hypomineral line of arrested bone growth observed by Spector et al. after space flight suggests that the mature matrix mineralizes, but the matrix which has not matured before exposure to space does not mature, and thus does not mineralize (Simmons et al., 1983). Research was performed on jaw bones, ribs, and long tubular bones. These data show that changes in the modelled skeleton suggestive of depressed bone tissue formation are not limited to weight-bearing bones.

Evidence is also available of differences in the extent of the metabolic process of compact and spongy bone in weightlessness. While osteogenesis is generally depressed throughout the bone as a whole, resorption of bone tissue appears to be depressed in compact structures and activated in spongy ones. It might be hypothesized that the earliest and universal response to the stress of weightlessness is inhibition of both metabolic processes for spongy as well as compact bone. In the next phase, the process of resorption is activated due to the decreased loading on bones. However, because of decreased metabolic rate in tissue of different density, when experimental observations were made, the spongy structures were in the second phase and the compact ones in the first. This hypothesis would predict that if weightlessness were prolonged, decrease in spongy bone would stabilize and compact bone would show effects characteristic of the second phase (i.e., activation).

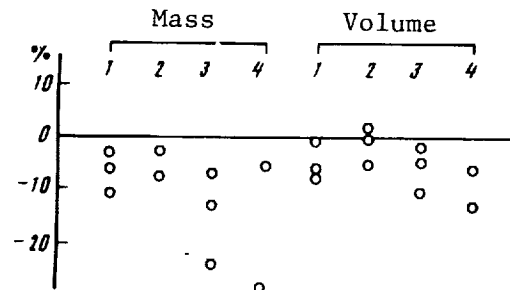


Figure 4: Change in mass and size of bones in rats in space flight (mean group data for various experiments)

1 - femur; 2 - tibia; 3 - distal epiphysis of the femur; 4 - head of the femur.



## MUSCULOSKELETAL SYSTEM

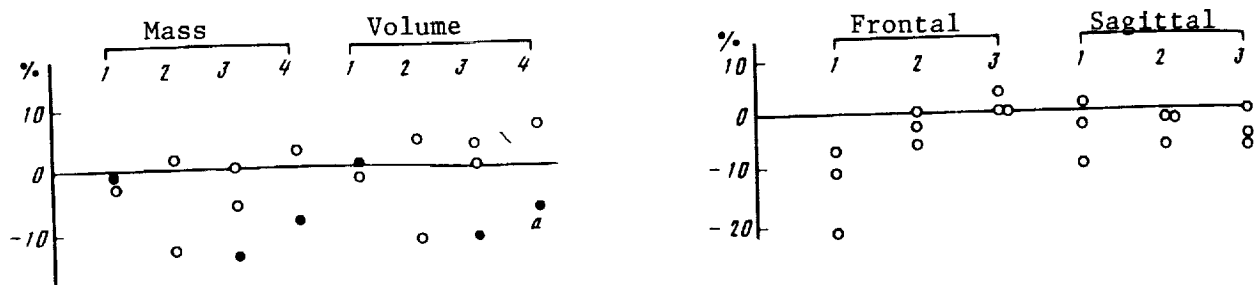


Figure 5: Change in mass and size of bones in rats on days 6 (a) and 25-29 (b) of rehabilitation

Key as in Figure 4

Figure 6: Changes in cross-sectional dimensions of the femur bones of rats in space flight

1 - thickness of cortical layer; 2 - width of diaphysis; 3 - width of marrow cavity

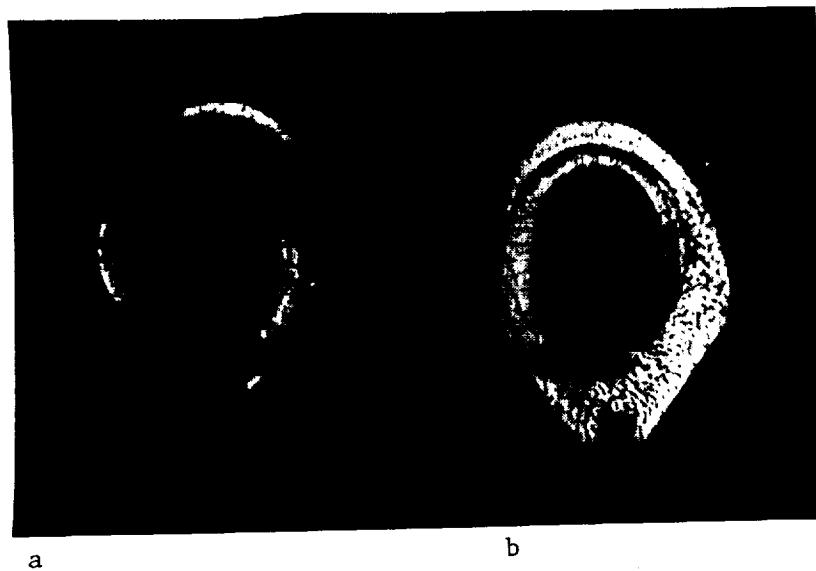


Figure 7: Microradiogram of the cortical layer of the femur  
a - vivarium group; b - flight group

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## MUSCULOSKELETAL SYSTEM

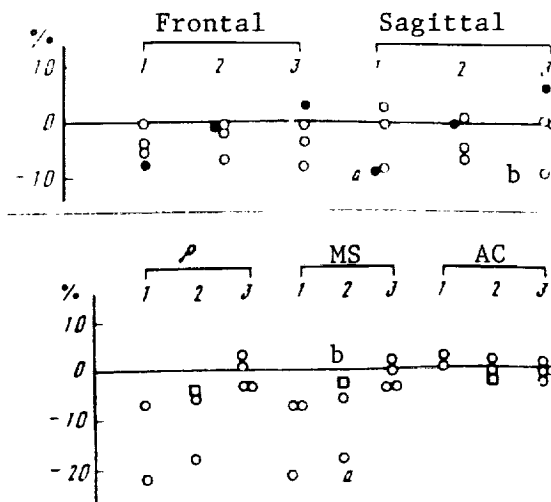


Figure 8: Change in the cross-sectional dimensions of the femur bones of rats postflight  
Key as in Figure 6

Figure 9: Change in density (P), mineral saturation (MS), and ash content (AC) in the bones of rats in space flight  
1 - distal epiphysis of the femur; 2 - head of the femur (a) and brachia (b);  
3 - bone tissue of the diaphysis

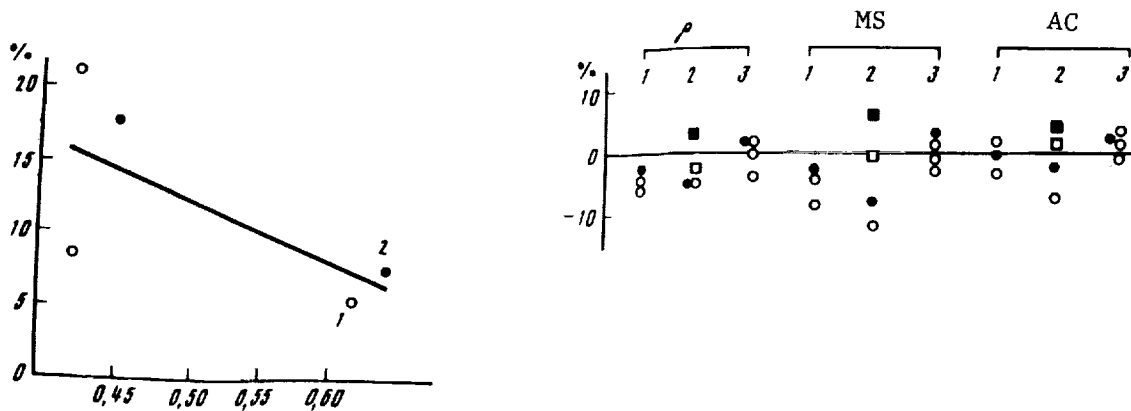


Figure 10: Severity of atrophy of the spongy bone structures as a function of their mineral saturation

1 - distal epiphysis of the femur; 2 - head of the femur.  
 $y = 33.79 - 43.03x$ ,  $r = -0.647$

Figure 11: Change in density, mineral saturation and ash content in the bones of rats postflight

Key as in Figure 9.

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Figure 12: Distal metaphysis of the femur bone of a control rat, x 87.5. Well-developed primary spongiosa of the metaphysis. Within the trabeculae of the primary spongiosa are the remains of cartilaginous substance of the cambial lamella. Stained with hemtaoxilin-eosin  
a - control; b - flight of 22 days

## MUSCULOSKELETAL SYSTEM

P1287(28/90) Stupakov GP, Volozhin.

*The skeletal system of experimental animals under conditions of weightlessness: The effects of space flight on the weight-bearing skeleton of rats: State of organic and mineral components.*

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость

[*The Skeletal System and Weightlessness*].

Volume 63 In series: Problemy Kosmicheskoy Biologii,  
Leningrad: Nauka; 1989.

Pages: 61-65.

Musculoskeletal System, Weight-Bearing Bones, Vertebrae, Femur, Organic and Mineral Components

Rats

Space Flight, COSMOS-936, -1129

**Abstract:** Disruption of bone restructuring and maturation in weightlessness suggests the possibility of changes in the composition of organic components. Potential change might affect collagen, and other organic compounds and their component parts, all of which participate in formation of the bone matrix. The concentration of collagen in the compact bone of the diaphysis was estimated on the basis of hydroxyproline concentration in rats after flight on COSMOS-936. In flight rats concentration of oxypoline was 19.84, while in control animals the analogous value was 20.78. This difference was not statistically significant. Histological studies of bones of rats flown on COSMOS-1129, which estimated level of collagen in the trabecular tissue of the vertebrae, also failed to find significant effects. This experiment also measured concentration of keratosulfate and chondroinsulfate (components of proteoglycans). Six days after reentry flight animals displayed elevated keratosulfate of the vertebrae. Chondroinsulfate was elevated on days 6 and 29 postflight. The authors suggest this may be due to retardation of bone tissue maturation in flight, compensated for by accelerated formation of new tissue during the recovery period. The data suggest that collagen synthesis alters in accordance with bone restructuring to maintain its normal concentration. Thus the quality of the matrix does not alter significantly, despite quantitative changes.

In additional studies the authors investigated concentration of the basic elements of hydroxyapatite -- calcium and phosphorus -- in the ash of the head of the femur (Table 2). Postflight concentration of calcium decreased by 4.5%, and showed a tendency for further decrease on day 9 postflight. Normalization occurred by day 29 postflight. No effects of flight were noted in phosphorus. Similarly, when calcium level was studied in cortical and trabecular tissues of vertebral bodies, no changes were noted in flight rats immediately after reentry, although on day 6 of recovery there was a decrease in calcium. Calcium normalized after 29 days. Decrease in calcium, while phosphorus remained the same, attests to a shortage of calcium ions from the surface of the crystal. As a result the C/P ratio decreases. The authors suggest that this effect is most likely due to a loss of anions from the bone, most probably  $\text{CO}_3$ .

If amorphous phosphates of calcium in bone are indeed more labile than crystalline hydroxyapatite, they should show greater loss in flight and thus the ratio of crystal and amorphous components should alter. The method of electron paramagnetic resonance spectroscopy was used to measure this ratio in the epiphysis and diaphysis of bones of flight rats. No significant effects were observed.

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Table 2: Characteristics of concentrations of Ca and P in the mineral components of the head of the femur (COSMOS-1129)

Stage of flight	Group	Concentration of elements, g per 100 g ash	
		Ca	P
Preflight	Baseline	47.4±1.3	18.8±0.27
Postflight	Control	47.1±3.0	18.0±0.20
	Flight	45.0±2.0	17.8*±0.34 [sic]
Day 6 postflight	Control	45.8±1.7	17.5±0.14
	Flight	43.4±0.7	17.7±0.29
Day 29 postflight	Control	40.5±1.1	17.5±0.43
	Flight	41.2±1.2	18.1±0.29

\* p < 0.05

## MUSCULOSKELETAL SYSTEM

P1288(28/90) Stupakov GP, Volozhin.

*The skeletal system of experimental animals under conditions of weightlessness: The effects of space flight on the weight-bearing bones of rats: Mechanical properties of bone tissue.*

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость

[*The Skeletal System and Weightlessness*].

Volume 63 In series: Problemy Kosmicheskoy Biologii,

Leningrad: Nauka; 1989.

Pages: 65-76.

Musculoskeletal System, Weight-Bearing Bones, Femur, Tibia, Humerus; Mechanical Properties

Rats

Space Flight, COSMOS-615, -782, -936, -1129

**Abstract:** Mechanical properties were studied in the femur, humerus, and tibia bones of rats flown on COSMOS-615, -782, -936, and 1129. When the tibia and femur were subjected to bend tests, their resistance to destruction (carrying capacity) was significantly depressed due to weakening of the proximal and distal metaphyses. These are the areas containing spongy bone that developed osteoporosis. Fractures occurred in precisely those areas, although the pressure was applied in the central area of the diaphysis.

Bone capacity to resist deformation (structural rigidity) changed little, and modulus of elasticity of compact bone was virtually unaltered. Energy of elastic deformation of the whole bone to overcome resistance to destruction and deformation decreased significantly. This is a measure of impact tolerance. Evidently these changes explain the fractures of the femur and tibia found in some animals after reentry.

Compression tests performed on samples from the medial portion of the diaphysis revealed virtually no decrease in supporting power, despite significant thinning of the cortical layer. This is attributable to some increase in strength of the bone substance of the cortical layer and is in good agreement with increased microhardness in the subperiosteal and subendosteal zones. The mechanical properties of the heads of the femur and humerus bones decreased significantly and continually, more so for the limit strength and modulus of elasticity of the femur than of the humerus. Microhardness of bone substance was virtually unaltered.

The authors argue that differences in the mechanical properties of compact and spongy bone are associated with the fact that the high metabolic rate of the spongy tissue initiates resorption processes very early and rapidly, against a background of inhibited osteogenesis. In compact bones, at this point in time, only changes associated with the latter process are evident. For this reason spongization of the cortical layer has not yet had time to occur, while bone tissue becomes more mature, explaining differences in strength characteristics.

During the recovery period further effects can generally be described as follows (Figure 14): the characteristics of compact substance of the diaphysis and spongy substance of the head of the humerus rapidly normalize, while the bend strength of the whole bone and the compression strength of the head of the femur remain depressed. This accords with data suggesting failure of density of spongy bone to recover at this point. However, when strength was tested in the head of the femur in COSMOS-1129 flight rats after 6 days of recovery, strength was below that on the day of reentry, while density had more or less normalized. At the same time there was a tendency for further decrease of concentration of calcium in the ash component. This alone could explain decrease in strength, since loss of calcium ions from the surface of hydroxyapatite crystals could weaken the physicochemical bonds in the collagen-crystal complex.

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Additional material on the association of physical and biomechanical properties is provided by a correlational analysis of these parameters in flight, synchronous, and vivarium groups of rats in a COSMOS-936 experiment. Table 4 shows that mineralization of the matrix and compact structure of bone are the most important factors determining its mechanical properties. Since density and mineral saturation involve these factors, it is easy to understand why they are correlated so highly with strength. Calcium level showed a weak association with strength. Phosphorus levels were not associated with mechanical strength.

Regression analysis was applied to data from a COSMOS-1129 experiment to evaluate total significance of physical parameters of the head of the femur to its total strength. Mechanical strength was most related to mineral saturation, with ash content and levels of calcium and phosphorus having little significance.

The authors argue that the data support a conclusion that decrease of bone strength in weightlessness is mainly due to resorption of part of the bone mass. However, this does not explain the continuing decrease in bone strength during the recovery period, when bone mass is increasing.

Data on the characteristics of bone destruction in animals after space flight is of interest. Resistance to destruction rests on three characteristics: inhibition of increase in cracks; extrusion of fibers from the matrix, leading to increased injured surface; and development of plastic deformation of the matrix, facilitating redistribution of stress in the tissue. Figure 16 shows that bones of flight rats, despite the presence of resorption areas, display all the normal processes.

Characteristics of microdestruction of whole femur bones on bending and heads of the femur on compression were studied using the method of acoustic emissions. Initial dispersive structural damage on bending was evoked by 40% lower loadings in experimental rats than controls. This difference did not disappear until 29 days postflight. For the head of the femur, no differences were found immediately postflight, but the level of stress evoking acoustic emission became progressively lower in flight rats during recovery.

Table 3: Change in microhardness in various zones of the diaphysis of femur bones of rats after a 19-day space flight, kgf/mm<sup>2</sup>

Group	Zone		
	subperiosteal	intermediary	subendosteal
Control	61.84±0.71	73.49±0.65	59.08±0.66
Flight	69.62±0.95*	71.81±0.93	69.22±0.78*

\* p < 0.001

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Table 4: Coefficients of correlation between parameters of physical and biomechanical properties of the femur bone of rats

	D **	MS	AC	Ca	P	$\sigma$	E	$\alpha$	$\epsilon$
Density**		0.99*	0.75	-0.21	-0.01	0.93	0.84	0.72	-0.53
Mineral Saturation			0.82	-0.15	-0.01	0.94	0.87	0.70	-0.56
Ash Content				0.21	-0.07	0.72	0.77	0.48	-0.52
Ca					0.14	0.15	0.06	-0.25	-0.26
P						-0.02	0.03	0.02	0.14
$\sigma$ (strength)							0.91	0.75	-0.53
E (modulus of elasticity)								0.5	-0.77
$\alpha$ (?)									0.23
$\epsilon$ (?)									

\* Coefficients greater than 0.42 are significant.\*\* Erroneously labelled mineral saturation, density is a guess based on the text.

Table 5: Data from multiple regression analysis of physicochemical and biomechanical parameters

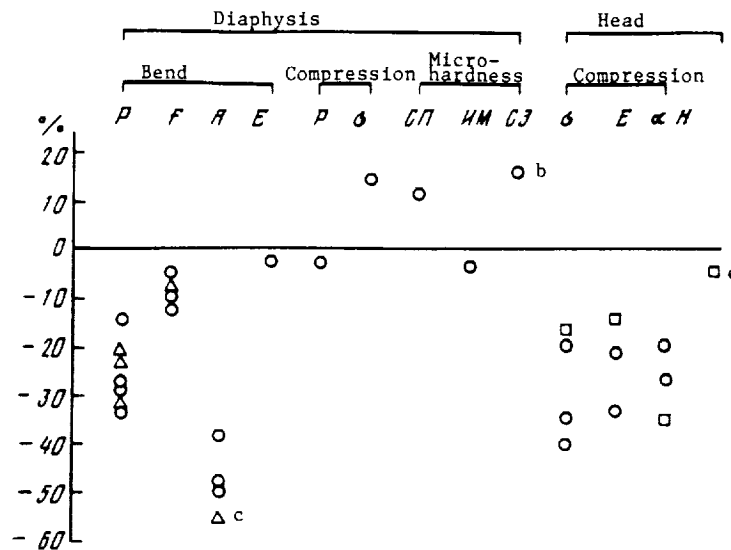


Figure 13: Change in mechanical properties of bones in rats undergoing space flight (here and in subsequent tables mean group values expressed as percentage change from vivarium control)

R - load carrying capacity, kfs; f - hardness; A - energy of elastic deformation, kfs/mm; E - modulus of elasticity, kfs/mm<sup>2</sup>; H - microhardness, kfs/mm<sup>2</sup>;  $\sigma$  - strength limit, kfs/mm<sup>2</sup>; a - femur bone, b - tibia bone; c - humerus bone. SP - subperiosteal, IM - intermediary, SE - subendosteal diaphysis.



## MUSCULOSKELETAL SYSTEM

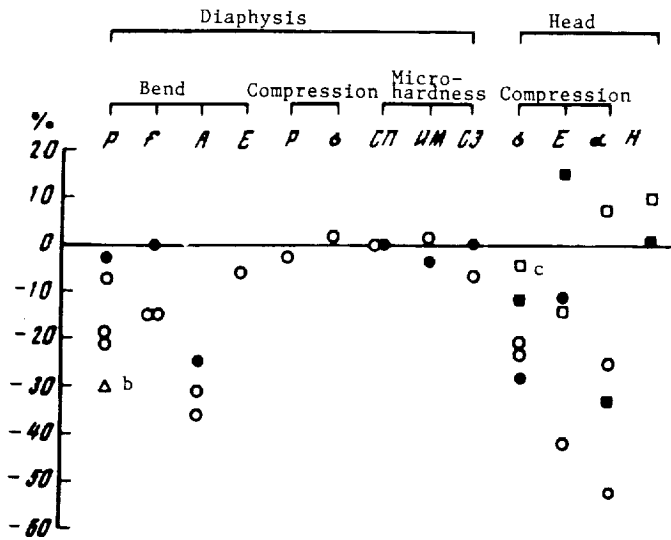


Figure 14: Change in mechanical properties of bones of rats during the readaptation period  
Key: as in Figure 13.

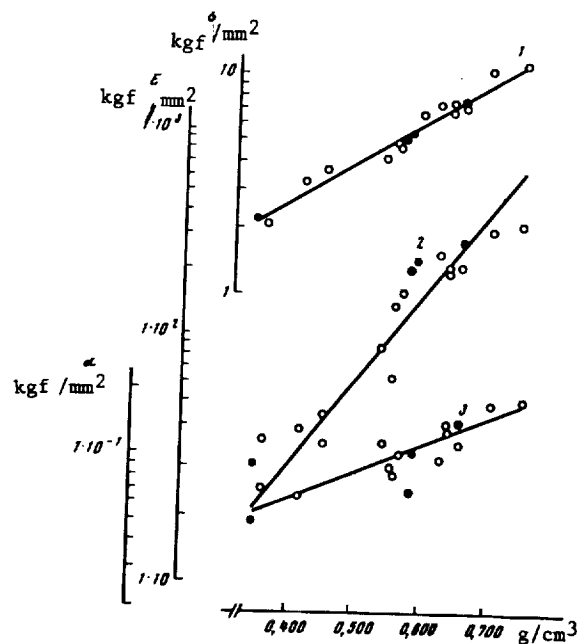


Figure 15: Mechanical properties of spongy substance of the head of femur bones of rats as a function of mineral saturation (mean group data)

1 - control, 2 - experimental group, 3 - recovery

$$1 - y = 0.524 \cdot 58.88^x, r = 0.982; 2 - y = 1.056 \cdot 38.28 \cdot 24^x, r = 0.958;$$

$$3 - y = 0.02 \cdot 18.11^x, r = 0.820$$

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Figure 16: Characteristics of destruction of the head of the femur bone of rats in the control (1 - 4) and experimental (5 - 8) groups

1, 5 - show traces of depression of the indenter, increased porosity of the structure of the head of the experimental group (X 30; 2.6 - X 100, 3/7 - X 500) - inhibition of cracks at various levels. One can see fibers extruding from the matrix - 3, 7, 4, 8 - area where the crack stopped

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## MUSCULOSKELETAL SYSTEM



Figure 16 (continued)

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## MUSCULOSKELETAL SYSTEM

P1289(28/90) Stupakov GP, Volozhin.

*The skeletal system of experimental animals under conditions of weightlessness: The effects of space flight on the weight-bearing bones of rats: Artificial gravity as a means to prevent bone changes in microgravity.*

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость

[*The Skeletal System and Weightlessness*].

Volume 63 In series: Problemy Kosmicheskoy Biologii,

Leningrad: Nauka; 1989.

Pages: 76-79.

Musculoskeletal System, Weight-Bearing Bones, Tibia

Rats

Space Flight, COSMOS-936; Artificial Gravity

**Abstract:** Research described in this section involved rats flown on COSMOS-936. A portion of the flight subjects were centrifuged at a gravity level of 1 g on the satellite. The experimental design involved 12 groups, including a ground centrifugation and a ground vertical centrifugation synchronous control. Animals were sacrificed and studied at different times, which made direct comparison of some parameters impossible.

Animals in group 1 were sacrificed on day 1 and of group 2 on day 3. Animals of the synchronous and vivarium control groups were sacrificed on days 4 and 7 of flight, directly after the flight and after a 25-day readaptation period. Direct photon absorptiometry was used to measure concentrations of minerals in the proximal epimetaphysial zone in freshly prepared tibia bones (5 bones from 5 animals in each group). Each bone was scanned in air four times using the Bone Scanner 7102 device and mean measurements were computed (measurement error did not exceed 4%). Results were expressed in grams of hydroxyapatite/cm<sup>2</sup> in the scanned area. Whole bones were weighed in air and water. Mass and volume were used to compute mean density per 1 g/cm<sup>3</sup>. Rats undergoing space flight but not centrifugation showed a 7.5% lag in absolute tibia weight gain compared to the synchronous group. Bone volume growth was also retarded (by 4%), indicating development of osteoporosis. This was confirmed by data on mineral concentration in the proximal epimetaphysial zone and the density of the bone as a whole. These parameters decreased significantly in flight rats. Artificial gravitation in weightlessness prevented these changes, and parameters of rats so treated were comparable to those of the synchronous animals. Thus acceleration of 1-g normalizes the effects of gravity on processes of physiological restructuring of bone. For technical reasons, it was not possible to directly compare bone porosity in the various groups of animals, but it appeared that when density of spongy structure (level of mineral component) was plotted against age, all growth curves fell on the same line with the exception of the group exposed to space and not centrifuged. The authors conclude that artificial gravity prevents development of bone atrophy in microgravity.

Table 7: Physical parameters of the proximal epimetaphysial zone of fresh tibia bones in rats of various groups in an experiment on COSMOS-936

## MUSCULOSKELETAL SYSTEM

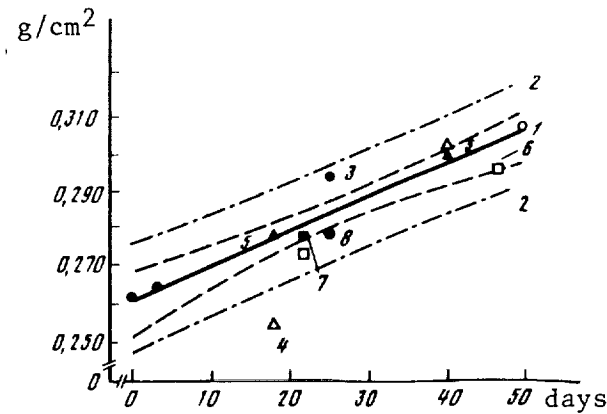


Figure 17: Concentration of mineral component in the proximal epimetaphysary zone of the tibia bones of rats as a function of age in COSMOS-936 experiment

1 - 95% confidence interval for mean values of the functions in two groups of animals (with the exception of the flight group); 2 - 95% confidence interval for additional observations (points indicate mean parameters in groups), 3 - vivarium control, 4 - flight group, 5 - flight group with centrifugation, 6 - synchronous group, 7 - synchronous conditions with centrifugation, 8 - "bios" (vertical centrifugation) control;  $y = 0.261 + 0.00087x$ ,  $p < 0.001$ ;  $r = 0.857$

## MUSCULOSKELETAL SYSTEM

P1290(28/90) Stupakov GP, Volozhin.

*The skeletal system of experimental animals under conditions of weightlessness: The effects of space flight on non-weight-bearing bones of rats.*

In: M157(26/90) Stupakov GP, Volozhin AI.

Kostnaya Sistema i Nevesomost'; Костная Система и Невесомость;

*[The Skeletal System and Weightlessness].*

Volume 63 In series: Problemy Kosmicheskoy Biologii,

Leningrad: Nauka; 1989.

Pages: 79-82.

Musculoskeletal System, Non-weight-bearing Bones, Ribs, Jaw, Teeth

Rats

Space Flight, COSMOS-936, -1129

Abstract: Soviets and Americans have studied the effects of space flights of 19.5 [sic., should be 18.5]-22 days on the dentomandibular system of rats. In one study a tendency was discovered for the bones and teeth of flight rats to decrease in ash content and Ca level, while P was unchanged. Animals centrifuged during space flight did not reveal any significant changes in density, mineral saturation, distribution of Haversian canals, ash content, or levels of Ca or P in the jaw bones or teeth compared with synchronous and vivarium controls.

A study of rate of formation of periosteal bones in the ribs and portions of the lower jaws covered by chewing muscles in rats flown in space for 18.5 days failed to reveal effects. Rate of bone formation and mineralization was depressed by 30-40% in sections of the lower jaw without muscle covering (molar area).

Morphometric analysis revealed a 29% decrease in the width of the periodontal ligament without changes in density of cell population, suggesting overall loss of bone tissue in microgravity. When cells of the periodontal ligament were studied using radioactive tagging, it was found that the number of precursors as well as the rate of their proliferation and differentiation dropped in space. Measurement of the nuclei of cells of the periodontal ligament revealed decrease in preosteoblasts due to inhibition of differentiation and thus a relative predominance of precursor cells. No differences were found 6 and 29 days postflight. This study confirmed the general nature of depressed osteogenesis in space.

In another study, in which rats spent 18.5 days in space, the number of osteoclasts in the area of the lower molars as well as in the metaphysis of the tibia was observed to be normal. However, ultramicroscopy revealed some signs of inhibition of their activity, such as delayed development of the fluted membrane and cytoplasmic vacuoles of osteoclasts, and also the resorption cavities. Nevertheless, resorption did occur in space during the flight of COSMOS-1129, although at a somewhat retarded rate.

The teeth of rats exposed to microgravity, as well as rate of appositional growth and maturation of the mineral matrix of incisors of the lower jaw, were unaltered.

Study of subperiosteal osteogenesis in the ribs revealed no differences in this process in rats flown in space, nor were there significant signs of increased resorption of bone tissue.

American scientists studied mineral metabolism using the radioisotope method. These results revealed a 22% decrease in resorption in the rib bones of flight rats.

Thus, the non-weight-bearing bones of animals exposed to microgravity display depression of both osteogenesis and resorption. While Ca, inorganic P, and oxyproline in the jaw, ribs, and incisors of flight animals were not different from those of control animals, it was found that

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collagen levels were depressed in the denser fractions of bone, elevated in the less dense and mature fractions. Since oxyproline level is a reverse function of skeletal growth, it may be concluded that inhibition of resorption leads to retardation and thus to aging of mature structures.

### PAPERS:

P1240(28/90)\*Gitsov LG, Burneva VG, Verbitskaya LB, Kabitsyna RA, Fedorenko VS.  
*Ultrastructural changes in neurons of the arcuate nucleus-medial eminence complex in rats irradiated with carbon ions and  $\gamma$ -radiation.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 34-36.

[6 references; none in English]

Neurophysiology, Neurons, Arcuate Nucleus, Medial Eminence

Rats, Female

Radiobiology, Carbon Ions,  $\gamma$ -Radiation

**Abstract:** The goal of this study was to compare the ultrastructural changes in neurons and other structures of the arcuate nucleus-medial eminence complex in rats irradiated with  $\gamma$ -radiation and accelerated carbon ions. Subjects were sexually mature female Wistar rats irradiated once with accelerated carbon ions with energy of 300 MeV/nucleon or  $\gamma$ -rays ( $^{60}\text{Co}$ ) at a dose of 2.0 Gy. Dose rate was 0.1 and 1.9 cGy, respectively. The animals were sacrificed 5 weeks after this treatment. Pieces of the brain were processed using traditional methods for electron microscopic study of brain tissue. Ultrafine sections were prepared and contrast stained and examined in an electron microscope. Before this a light microscope had been used to study semithin sections stained with toluidine blue.

In animals exposed to carbon ions, changes in ultrastructure of neurons of the arcuate nucleus, and their processes and synapses, were highly polymorphic. Some neurons displayed chromatolytic changes, which are reversible and suggest increased functional activity of neurons as a compensatory mechanism. Other neurons displayed hyperchromic effects varying in severity, suggesting decreased cell functional activity and degenerative atrophy of cells. Such changes are not reversible. Marked changes were also noted in the neuropil of the arcuate nuclei, both chromatolytic and hyperchromic. In the medial eminence of rats irradiated with accelerated ions, the apical cytoplasm displayed light vacuoles, swollen mitochondria, and a scarcity of microfibrils. However, intercell contacts were undamaged and the blood-brain barrier maintained its function.

Rats subjected to  $\gamma$ -irradiation at the same dose also displayed changes in the arcuate nuclei. However, there were significantly fewer hyperchromatic changes than after exposure to carbon ions and significantly fewer electron-dense formations. The authors conjecture that the ultrastructural changes in the neuropil after exposure to carbon ions and  $\gamma$ -rays (formation of electron dense inclusions similar to secondary liposomes) may be a sign of premature aging.



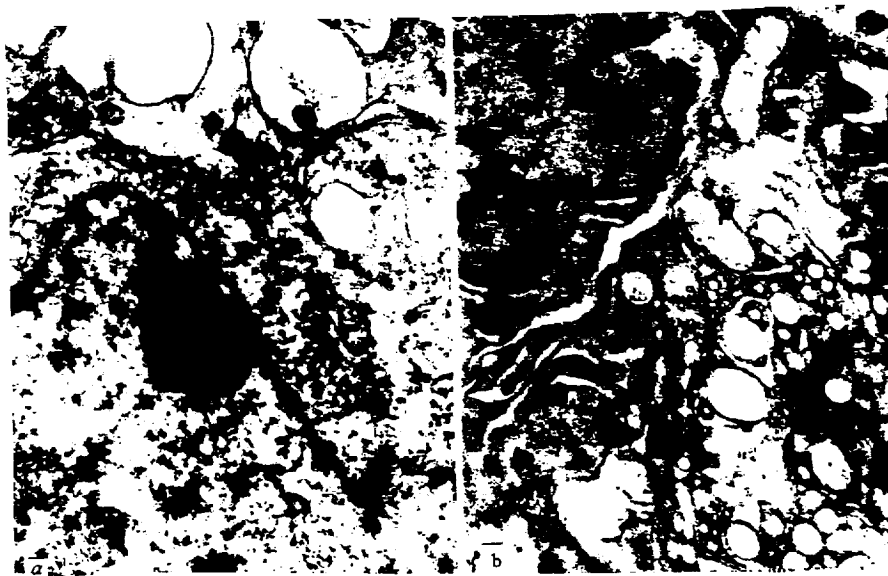


Figure 1: Changes in neurons of the arcuate nuclei after exposure to carbon ions  
a - chromatolytic changes in a neuron with cytoplasmic vacuolization. Mag 10,000 X, b - hyperchromic changes of the neuron with destruction of organelles and vacuolization of cytoplasm Mag. 10,000 X



Figure 2: Change in neuropil of the arcuate nucleus after exposure to carbon ions  
a - edema and swelling of the mitochondria, destruction of dendro- and axoplasm, sharp decrease in number of synaptic vesicles. Mag 20,000 X. b - "dark" (hyperchromic) changes in dendrites and formation of electron-dense pathological structures. Mag. 6000 X

Figure 3: Deposits of granules of nitric acid lanthanum on the surface of endothelial cells of the arcuate nucleus

P1254(28/90) Yegorov AYe, Prosvernitsyn SA.

***On the genesis of postradiation edema of the brain.***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 873-874..

Authors' affiliation: Scientific Research Institute of Military Medicine

Neurophysiology, Brain, Edema, Blood-Brain Barrier

Rats, Males

Radiobiology,  $\gamma$ -Irradiation; High Doses

**Abstract:** The blood-brain barrier plays an important role in supporting stability of brain functioning. However, data in the literature on the effects of ionizing radiation on the blood-brain barrier, especially in large doses, are few and contradictory.

The goal of the present work was to elucidate the extent to which blood-brain barrier permeability is disrupted in the period immediately after irradiation with high doses of ionizing radiation, and also to study certain possible mechanisms underlying the development of such disruption.

Experiments were performed on white outbred male rats exposed to a single session of whole body irradiation with  $\gamma$ -quanta at a dose of 150 Gy. Permeability of the blood-brain barrier was estimated on the basis of quantity of radionuclide tracer ( $^{14}\text{C}$ -urea) entering brain tissue. An electron microscope with a television display was simultaneously used to record presence of swelling and edema in the neurons of neocortical and medullary astrocytes.

This research showed that 0.5, 1, 2, 3, and 4 hours after irradiation of the animals, accumulation of  $^{14}\text{C}$ -urea in brain tissue decreased by 20-40%. Indicators of edema observable with the electron microscope 0.5 hours after irradiation were moderate, consisting primarily of lightening of the matrix of synaptic terminals and scattered astrocytic processes. After 1 hour, the indicators of edema were more severe, developing as a rule in the neuronal cytoplasm of the granular medullary layer. A characteristic of these edematous changes was unaltered width of the intercellular spaces and edematous neuronal changes that were independent of the location of capillaries. The extent of edemically altered areas during this period was 6%. Two hours after irradiation edematous changes had increased. However, their main locus was now the astrocytes, especially the perivascular processes. The extent of the edemic areas increased to 12%. Subsequently, edema became classifiable as destructive and affected areas reached over 20%. At all the time intervals studied, the major elements of the blood-brain barrier were retained, but there were ultrastructural indicators of decreases in active transport of fluid across the endothelium, as demonstrated by the decreased number of pyknocytotic vesicles in the luminal portion of the endotheliocytes.

The rapid development of edema in nerve cells, accompanied by retention of the intercellular spaces and components of the blood-brain barrier, with decrease in its permeability by  $^{14}\text{C}$ -urea suggest that the edema observed is cytotoxic in origin and develops as a consequence of inadequate fluid elimination from nerve cells through the astrocytes and blood-brain barrier.

The results obtained suggest that the most promising area to search for means to correct postradiation brain edema is among agents increasing active elimination of fluid from cytoplasm.

P1255(28/90) Antipov VV, Fedorov VP, Ushakov IB.

***Structural and metabolic aspects of modification of radiation effects on the central nervous system.***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 861-862..

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Voronezh Medical Institute

Neurophysiology, Central Nervous System, Metabolism

Rats, Dogs

Radiobiology, Radiation; Modifiers, Hypoxia, Hyperoxia, Alcohol, Acceleration, Vibration

**Abstract:** An experiment was performed on 2000 animals (rats, dogs) to investigate the structural and metabolic bases for modification of radiation-induced changes in the central nervous system by such factors as hypoxia, hyperoxia, alcohol intoxication, super-high frequency radiation, vibration, and longitudinal acceleration.

It was demonstrated that even low intensities of these factors may modify the structural and functional effects of radiation during the first few minutes and hours after irradiation (rats - head irradiation 10, 50, and 200 Gy; dogs - head irradiation 75 Gy, whole-body irradiation 5 Gy). Rational use of the multifactor approach to analysis of the radio-modifying effects observed was shown to be a promising technique.

After structural and functional analysis of the numerous possible combinations of ionizing radiation and other environmental factors, the authors found that among the most reactive systems were the system that supports interneuronal integration (synapses, blood-brain barrier) and the protein synthesizing system. Changes in synapses depended on dose of irradiation and its temporal position with respect to the other factors. In virtually all cases in which irradiation followed exposure to other factors, changes in synapses were attenuated. But when irradiation was simultaneous with or preceded exposure to another factor, changes were intensified.

It has been conjectured that the state of the central nervous system of a subject exposed to one or a number of factors may be described by the distribution of fluid, sodium, and potassium in various areas of the central nervous system, i.e., the hydration-electrolyte pattern in the brain, which is directly associated with the functioning of the blood-brain barrier. When exposure time varied, virtually all possible types of biochemically pathological electropherograms were recorded. The direction of changes depended on phase of development of the process. The most reactive of the structural elements of the blood-brain barrier was the perivascular-astrocyte pedicle.

It is very important in the authors' opinion to understand that there are both positive and negative aspects to the modifying effects of each factor studied, depending on the criteria used. This is particularly obvious when the doses of the nonradiation factors, such as oxygen and hypoxia, are high.

In attempting to draw conclusions concerning radiation tolerance of the central nervous system under conditions of exposure to other factors, it should be noted that at present definitive answers cannot be provided in the study of combined effects. The nature of an effect on the nervous system depends on magnitude, time parameters, sequence, interval, and dependent variable. Therefore, the problem of the combined effects of factors on the central nervous systems awaits new approaches, computer-based as well as functional and structural.

P1256(28/90) Fedorenko BS, Kabintsyna RA, Smirnova OA, Krivitskaya GN, Verbitskaya LB, Derevyagin VM, Gitsov L, Burneva V, Popov VI, Portman AI.

***Morphological changes in brain neurons in rats irradiated with accelerated charged particles.***

In I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 895-896..

Authors' affiliation: Institute of Biomedical Problems, USSR Ministry of Health; Brain Institute, USSR Academy of Medicine; Institute for the Study of the Brain, Sofia, Bulgaria

Neurophysiology, Brain Neurons

Rats

Radiobiology, Accelerated Charged Particles

**Abstract:** Research in which rats were irradiated with protons of energy 50 and 645 MeV and  $\gamma$ -irradiation with  $^{60}\text{Co}$  has shown that the number of dystrophic changes in neurons increases with increasing radiation dose and time elapsed after irradiation. In intact rats the quantity of dystrophic changes in neurons of the sensorimotor cortex of the brain remained constant at a level of 2-4%. In irradiated rats, there was a progressive decrease in the number of unaltered cells with time. The rate of increase was a function of dose magnitude. Irradiation of animals in a dose of 6.0 Gy led to decreased number of unaltered neurons 6 months after irradiation up to 18.9%, 44.7%, and 29.6% for proton doses of 50 and 645 MeV and  $\gamma$ -radiation, respectively. Study of dystrophic changes in neurons 3 months after irradiation by protons of 9 GeV and helium ions of 4 GeV/nucleon in a dose of 1.0 Gy revealed damage equivalent to that from  $\gamma$ -radiation of 6.0 Gy. A comparative analysis of morphological changes in neurons after irradiation of animals with carbon ions with energy of 4 GeV/nucleon or with  $\gamma$ -radiation from  $^{137}\text{Cs}$  in doses of 0.25-4 Gy was performed. The analysis confirmed that effects are an increasing function of radiation dose and facilitated identification of certain characteristics of the biological effects of heavy ions in comparison to those of standard radiation. In particular, carbon ions induce changes marked by nonreactivity of neuroglia, while changes due to  $\gamma$ -irradiation are mainly of the reactive type (hyperplasia of glial elements). The extent of dystrophic changes in neurons of  $\gamma$ -irradiated rats increased linearly with dose, while after exposure to carbon ions the curve was linear only up to a dose of 2.0 Gy, after which it began to level off. Doses of  $\gamma$ -radiation of 0.25 and 0.50 Gy had virtually no effect with respect to cellular changes, while irradiation with carbon ions at a dose of 0.25 Gy led to structural changes in neurons and damage to cytoarchitecture. In the remote period after irradiation with streams of carbon ions with energy of 300 MeV/nucleon ( $10^4$  particles/cm<sup>2</sup>), damage to ultrastructure in the arcuate nucleus-medial eminence structure was found to be 1.5 to 2 times more severe than that observed in nonirradiated animals or those irradiated with  $\gamma$ -radiation at a dose of 1.0 Gy. Moreover, changes were noted in the shapes of cells and their nuclei, the nucleus:cytoplasm ratio and other parameters. In the medullary cortex there were damage sites with indicators of increasing irreversible changes.

The analysis performed supports a conclusion that helium and carbon ions, as well as protons with energy of 9 GeV, have higher relative biological effectiveness than standard radiation. The RBE of such radiation fluctuated between 8-16 and 1.5 as a function of various factors.

P1246(28/90)\* Mikhaylov VM, Kornilova LN, Zhernakov AF, Voskresenskiy AD, Pomeŭov YuD, Alekseyev VN.

***Correlation between orthostatic tolerance and status of the vestibular function in humans after long-term space flights.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24 (1):49-50; 1990.

[9 references; 1 in English]

Neurophysiology, Vestibular Function, Orthostatic Tolerance

Humans, Cosmonauts

Space Flight, Long-Term, Salyut-6

**Abstract:** This work attempted to determine whether there was a correlation between parameters of orthostatic tolerance and vestibular function in members of prime crews of Salyut-6 during the early period of readaptation to Earth's gravity. Postflight studies were made on 10 cosmonauts who had spent 75 to 184 days in orbit. During flight all cosmonauts exercised on the ergometer and treadmill and during the last stage of their flight also underwent lower body negative pressure training. On the last day of their flights all cosmonauts received salt and fluid supplements. Tilt tests, involving 10 minutes in upright position on a tilt table, were performed on the day of landing and on days 1, 5-6, 13 and 18 of recovery. The parameter taken to be indicative of orthostatic tolerance was a compound index encompassing changes in several cardiovascular parameters. The index had a value of from 1 to 5, with 5 indicating high tolerance. Vestibular tests were administered on the days of landing and days 5-6 and 9-10 of recovery. Vestibular function was assessed on the basis of studies of spontaneous and vestibular nystagmus, fixational eye movements, tracking, and responses of the vestibulo-ocular reflex to swinging and head turning with eyes closed and various fixation tasks, as well as optokinetic nystagmus. These studies were performed with subjects in a sitting, horizontal, or head-down (-30°) position. Vestibular reactivity was assessed using cupulometry. Results of study of the vestibular function were summarized on a 1-5 rating scale, in which 5 was normal and 1 was severe vestibular dysfunction. Coefficients of pairwise correlation were computed for orthostatic tolerance and severity of vestibular changes to assess the association between them and also to investigate whether it was possible to predict dynamics of orthostatic and vestibular reactions from results of the first preflight examinations.

Baseline values on both rating scales were predominantly 5, with isolated instances of 4. On the day of landing the orthostatic index varied from 1-3 and that for vestibular function from 1-4. On day 5-6, both indices tended to normalize, but they were still below baseline. The vestibular function had recovered by day 9-10 in most subjects, and orthostatic tolerance by days 13-18. On the basis of postflight dynamics of parameters, measurement at days 5-6 of recovery was selected for computing correlations. When scores were standardized the correlation between orthostatic tolerance and vestibular function was significant. The correlation between vestibular function on the day of landing and day 5 of recovery was high and significant, and the analogous correlation for orthostatic tolerance was relatively high, but was not statistically significant due to small sample size.

The results are interpreted as confirming the hypothesis that there is correlation between orthostatic tolerance and the state of vestibular function in the initial period of readaptation after long-term space flight. Correlation between values of each of the parameters on the day of landing and on day 5-6 of recovery is interpreted as demonstrating that individual differences in orthostatic tolerance (not statistically significant) and especially vestibular function are retained for several days after flight, making prediction of recovery dynamics theoretically possible, at least with regard to vestibular response.

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Table: Correlations between orthostatic tolerance (OT) and vestibular function (VF) in the postflight period (OT=0 and VF=0 on the day of landing, OT=5 and VF=5 on day 5-6 or recovery)

Correlation coefficient	OT=5	VF=0	VF=5
OT=0	0.61	0.58	0.48
OT=5		0.26	0.52
VF=0			0.86*

\*  $p < 0.01$

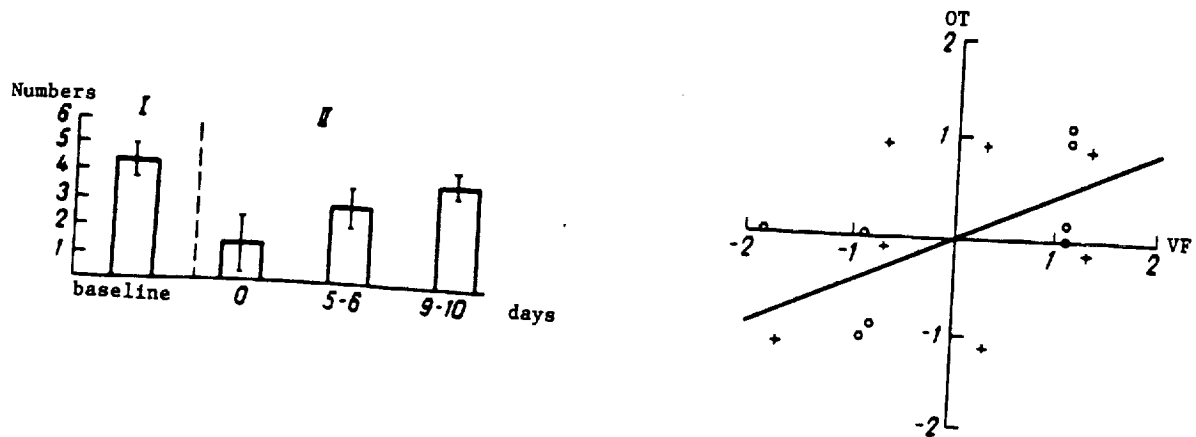


Figure 1: Dynamics of state of vestibular function postflight  
I - preflight baseline, II - postflight recovery period

Figure 2: Correlations between normalized estimates of OT and VF  
Dots - day of landing; crosses day 5-6. Regression line is described by equation:  $OT=0.42VF$

P1247(28/90)\* Vorob'yev OA, Zaritskaya VV, Krylov YuV.

*The relationship between vertical optokinetic nystagmus and susceptibility to motion sickness in humans.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 49-50; 1990.

[12 references; 7 in English]

Neurophysiology, Vertical Optokinetic Nystagmus

Humans, Males, Individual Differences

Motion Sickness

**Abstract:** To test the hypothesis of the possible relationship between optokinetic nystagmus and motion sickness in space, this study investigated dynamics of vertical optokinetic nystagmus in individuals differing in their susceptibility to motion sickness. Subjects were 92 healthy men, aged 18 to 22. Visual stimulation was provided by an optokinetic drum containing alternating white and black stripes. When the drum was rotated, the stripes were displaced up or down with angular velocity of 120°/sec. Subjects viewed the stripes in either a seated or head-down (-10°) position. Nystagmus was recorded using electronystagmography. Resistance to motion sickness was studied using a vestibulometric test in which subjects underwent continuous precessional and Coriolis acceleration first with their eyes open. Subsequently a screen was placed in front of the subjects to limit visual stimulation in the center of the visual field. The test was terminated on occurrence of nausea. The maximal duration of the test was 3 minutes. Motion sickness severity was rated.

On the bases of results of vestibulometry, subjects were divided into three groups. Subjects in group 1 (n=29) displayed no motion sickness, those in group 2 (n=34) developed moderate motion sickness symptoms, and group 3 subjects (n=29) developed severe motion sickness. Upward nystagmus was decreased in head-down position for subjects in groups 2 and 3, while downward nystagmus remained the same. The reverse was true for subjects in group 1. In groups 2 and 3 with subjects in a seated position, upward nystagmus was more pronounced than downward, with the reverse asymmetry in head-down position. Differences between upward and downward nystagmus were not significant in either position or for any group.

The authors conclude that the combination of vestibular stimulation and fluid shifts in the cranial direction leads to characteristic modifications of vertical optokinetic nystagmus, more pronounced in those subject to optokinetically induced motion sickness. The reversal of vertical-horizontal asymmetry in head-down position toward predominance of negative nystagmus may serve as a prognostic indicator of susceptibility to motion sickness.

Table 1: Mean values of parameters of vertical optokinetic nystagmus studied in sitting and head-down positions

Table 2: Characteristics of symmetry of slow phase rate of vertical optokinetic nystagmus in sitting and head-down position

Table 3: Frequency of reversal in direction of asymmetry of rate of slow phase of vertical optokinetic nystagmus (in % of group) when subjects are moved from seated to head-down position (+ predominance of downward nystagmus; - predominance of upward nystagmus)

Group	Sign change from + to -	Sign change from - to +
Not susceptible	16.0	16.0
Moderately susceptible	13.3	26.7
Highly susceptible	23.1	19.2



## PERSONNEL SELECTION

P1287(28/90)\*\* Medenkov A, Tret'yakov N.  
*Can the psychologically "incompatible" work together?*  
Aviatsiya i Kosmonavtika.  
1990(2): 32-33.  
Authors' Affiliation: USSR Medical Corps

Human Performance, Small Group Performance  
Humans, Aviation Personnel, Military  
Psychology, Personnel Selection, Compatibility

Translation: The pace at which psychological knowledge is being applied to the restructuring of the economic, social, and political life of our country has been extremely slow. Delay in applying this knowledge to human factors issues relative to group performance in the military has been unjustifiable. Why is this happening and what are its consequences?

The psychological principles governing development of the personality and regulation of behavior and interpersonal relationships are also highly relevant to the issue of collaborative work among various categories of aviation specialists. Optimizing interactions of flight crews, teams manning ground monitoring and radar stations, and shifts during routine military training activity should qualitatively improve combat readiness of divisions and units, as well as flight safety. It is important to realize that what is required here is not additional expenditures for upgrading technology or developing special training equipment, but merely consideration of the psychology of personality. This is the business of commanders and political officers who must know the laws governing human interactions and be able to use them skillfully.

What is psychological compatibility and can two or more people really be incompatible?

This concept has a number of facets. On the one hand, compatibility is treated broadly and encompasses all the psychological aspects of interpersonal relationships -- informational, economic, intellectual, ethical, etc. On the other hand, it is understood more narrowly as a characteristic of interactions among members of a group with a formal, frequently work-related purpose. The emotional aspect is especially important here.

For example, people are psychologically compatible when they are all sociable, considerate, empathetic, self-critical, etc. Groups are highly effective when the personality traits of the group members are complementary or similar. Crews, teams, and shifts in which members have been selected in accordance with compatibility considerations demonstrate the best performance and lowest rates of errors and flawed decisions. In almost one quarter of the cases, when air traffic controllers are selected randomly for a shift, some members will be psychologically incompatible. This hurts morale and substantially diminishes work efficiency.

The psychological compatibility of individuals on an existing crew, team, or shift can be assessed by determining how they feel about each other, using so-called sociometric methods, as well as by studying their personality traits. However, it is not advisable to try to evaluate the nature of interactions directly. A number of indirect techniques make it possible not only to evaluate, but also to rank order the desires of people to work together.

Good morale is achieved if the head of a group and his deputy are in sympathy, while other group members express willingness to work together, even if the feeling is not mutual in all cases.

Poor morale can be expected in groups containing individuals who are not in sympathy with each other or the group leader. This is especially common where groups include people who are

## PERSONNEL SELECTION

extremely outgoing or sensitive, or reticent to the point of alienation in their interpersonal relationships.

Sociometric methods are effective [in selecting compatible small groups] when members of the larger work group from which a crew, team, or shift is to be formed have already had experience working together and know each other well. If this is not the case, psychological compatibility can be predicted from the results of comparative analysis of individual personality traits. Such analyses can be based on past evaluation, observations, interviews, and data from specialized testing. What guidelines should be followed here?

The highest degree of compatibility is observed in groups where the leaders have clear leadership traits and the majority of subordinates are sociable and energetic. It is difficult to staff crews, units, and shifts with people who are markedly reticent, depressive, emotionally labile, impulsive, anxious, etc. Such individuals are rarely compatible with each other. However, problems rarely arise when such people are surrounded by outgoing people who form simple direct relationships, are sincere, and able to understand others readily.

Is it possible to affect psychological compatibility?

It is well known that when members of a group keep each other informed about their actions and discuss matters openly and freely, dispelling ambiguity where objectives are not obvious, this can forestall individuals who are prone to anxiety and brooding from misinterpreting the actions of others.

The most important factor for work group cohesiveness is acceptance of common goals and objectives by all members. We are speaking here about true acceptance, not formal acquiescence. For this reason, serious individualized efforts must be made to make the goals and interests of the group personally significant to its individual members. Here we are speaking not only and not even primarily about material benefits and incentives, as about psychological satisfaction with one's position and role. The cohesiveness of a work group increases when the success of joint efforts is perceived as resulting directly from interactions and collaborations among individuals.

And what fosters psychological incompatibility? One important factor is the drawing of gratuitous distinctions among individual group members when group actions are evaluated. Thus, when a flight has not been very successful overall, it is not a good idea to praise the pilot for a successful landing, while reproaching the navigator for errors in calculation. If such things are done, crewmembers subconsciously develop negative reactions detrimental to cohesion. It is even worse if this is compounded with the consciousness that someone else's actions or failure to act are responsible for one's own needs not being met.

Mutual dislike can also be fomented by similarity of personality and emotional traits. The presence of high anxiety levels in two interacting individuals may exacerbate these traits and lead to the development of psychological incompatibility.

The reason for conflicts is often lack of understanding by subordinates of the motives underlying the behavior of their leaders. Thus, for example, a highly competent officer who was expert in his area of work was appointed head of a shift for one of the air traffic control centers. He was exacting, high-principled, and demanded order in all things. At first, he encountered distrust and hostility on the part of his subordinates. But suddenly everything changed! What happened?

The head of the center made him responsible for preparations for a field day. It turned out that off the job he was sociable and capable of inspiring others, showing originality and flexibility.

## PERSONNEL SELECTION

Everyone came to understand that his strictness on official matters was a result of his intense sense of responsibility for the work that had been entrusted to him.

One should not conclude that all conflicts in groups are rooted in personality traits. Deficiencies in upbringing, low levels of culture, and individual psychological traits in their extreme manifestations frequently give rise to hostility within the work group. Lack of consideration for one's colleagues, attempts to impose one's opinion, and lack of respect for others frequently lead to resistance to completely reasonable and justified suggestions, recommendations, and requests.

This may occur when a leader, through constant reproaches and corrections, creates a climate in which even his most sensible suggestions are perceived negatively. For this reason, it is important to determine the extent to which social, psychological, and personality factors and deficiencies in upbringing are responsible for deterioration of relationships among co-workers. Only then will the results of [objectively] adverse factors not be falsely attributed to psychological incompatibility. The success of the joint efforts of commanders, political officers, and psychologists to create cohesion and mobilize work groups depends on accurate diagnosis.

If a leader is to be close to his people and the human factor is to be enlisted to improve performance, the leader must understand the needs of his subordinates, as well as the psychological principles underlying the structure of joint activity. Much, and sometimes even everything, hinges on successful interactions within a crew, team, or shift.

## PSYCHOLOGY

### PAPERS:

P1268(28/90)\*\* Kuznetsov ON, Yegorov BA, Frantsen BS.

*Characteristics of color selection in the Luscher test as an indicator of typical emotional status of flight personnel.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):15-18; 1990.

[8 references; none in English]

Psychology, Emotional Status

Aviation Medicine, Flight Crews

Color Preferences

Abstract: The "Luscher Color Test" [involving choice of "preferred" member of all possible pairs of a set of colors], typically used for athletes, is proposed as an accurate short-cut test for evaluating the emotional status of flight crews. This paper describes a preliminary attempt to norm the test for flight personnel. Subjects were 40 flight instructors who selected colors on days when they did not fly and right after day and night flights. Observations were made during the beginning of intense training flights (spring) and during the final period of these flight (fall). Eight colors from the Luscher set were used: primary colors — blue, green, red, yellow; mixed colors of violet and brown; and achromatic black and grey. Choices of flight personnel were compared to a previous norming group

The four "least preferred" colors of the set [blue, brown, grey and black] were identical in order for pilots and the general population. Differences in the "most preferred" colors involved the fact that the flyers preferred the "cool" colors of green and violet to the "warm" colors of red and yellow. This difference is interpreted as suggesting that the affective status of the pilots is under greater counterbalancing control. The positive emotions, associated with selection of warm colors, is moderated with the desire to be guided by reality, and such traits as persistence, goal-directedness, firmness, reliability and accuracy. The authors conclude that this test is promising for use in evaluating emotional status of flight personnel.

## PSYCHOLOGY

P1276(28/90)\*\*Shlyk GG, Shirvinskaya MA, Rotenberg VS, Yefimova MYa, Eliava VM, Sheremet IP, Kolpakova NF.

***The role of typological differences in behavior of animals during adaptation to an extreme stimulus.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2):38-41: 1990.

[10 references; 2 in English].

Adaptation, Extreme Situations, Conditioned Responses, Recovery

Primates, Rhesus Monkeys

Psychology, Typology, Behavior

**Abstract:** A total of 60 male rhesus macaque monkeys were studied in connection with preliminary work to train animals for experiments on COSMOS biosatellites. During the first step of training the animals were acclimatized to the primate chair. In one paradigm, animals were presented with a positive and differential stimuli on a light display for 0.5-1 second. The animals were rewarded with juice for the correct response of pulling a lever when the positive stimulus was presented. For a false alarm or failing to pull the lever at the positive signal, the animals were penalized by a delay in presentation of the next signal. In the second paradigm, the animals had to learn to push a pedal with a force of a certain amplitude three times and then hold the pedal in a certain zone for 1-2 seconds. Performance was evaluated in percentage of 100 trials. During development of the reflexes animals were transported from city to city in connection with flight preparation and moved from the primate chair to the Bios-Primat capsule, in which they were isolated and subjected to rigid fixation. They were placed in the capsule in a ground mock-up of the biosatellite and subjected to acceleration and "white noise." The effects of these factors were evaluated on the basis of retention of the conditioned response and rate of recovery. The monkeys were divided into three groups. Group 1 contained monkeys that retained the response or recovered it in the first 3 days. Group 2 contained monkeys that recovered the response in 4-5 days, and group 3 required 6 days or more for recovery. Behavioral typology of the animals was studied using two independent tests. The first was the "exploration of an unfamiliar space," which is analogous to the "open field" test for small laboratory animals. In this test the animals were placed one by one in an unfamiliar enclosure 3X4 meters in size for 20-30 minutes. The enclosure had climbing platforms along one wall. Observed parameters included: period of time animals remained in a single spot, motor activity, and nature of movements within the cage. The second test involved reactions of the animals to an unfamiliar object. The animals were restrained in the primate chair with some freedom of movement and were given two groups of objects, some shaped like fruit and vegetables, others in the form of animals that made noise when squeezed, or mechanical toys. Each object was placed in front of the animals on a tray for 2-3 minutes and the animals facial expressions and behavior recorded.

The animals were assigned to the following categories on the basis of behavior: 1A — animals actively moving around and crossing the cage (exploratory behavior); 2A — animals actively moving along the wall of the cage and in the upper portion with a posture and expression of defense or threat to the experimenter (active defensive behavior); 3A — animals with low motor activity, moving along the walls and in the upper portion of the cage with vocalization and expressions characteristic of warning (low level of exploratory activity); 4A - animals spending 5-15 minutes in the upper portion of the cage, moving little or sitting in one spot (passive defensive behavior, failure to explore).

Reactions to the unfamiliar object were also classified. Type 1B — exploratory (animals examined the object, picked it up, put it in their mouths); 2B — active defensive behavior (pushed object away, defensive posture and vocalization); 3B — passive defensive (turning away, signs of fear, but absence of actions to get rid of the object); 4B — capitulation response

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(passive fear with defecation). Results of the two tests corresponded completely in 44% of the cases where animals showed response types 1 or 4, and in 40% of the cases for types 2 and 3. Only 4 of 48 cases displayed a marked discrepancy between the responses to the two situations.

Results on recovery of conditioned response showed that the most disruptive effects were those involving marked change in experimental situation (intercity move, transfer from trainer to capsule), and that effects were more pronounced in the second, more difficult paradigm. When conditioned reflexes were compared in monkeys showing type 1 (active exploration) and type 4 (passive defensive) type response it was found that rate of recovery of conditioned response was faster in animals of type 1 and 2 than type 4. Animals with marked passive reactions showed poor adaptation to confinement in the capsule or mockup, while animals of types 1 and 2 adapted relatively well. The results are interpreted as indicating that high levels of exploratory activity facilitate successful adaptation to stressful situations.

Figure 1: Rate of recovery of conditioned responses in extreme situation in paradigm 1 (a) and 2 (b)

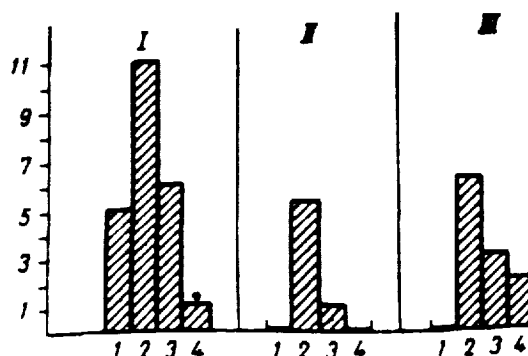


Figure 2: Rate of recovery of conditioned responses in the Bios-Primat capsule in paradigm 2 (better than 60% correct) in monkeys ranked on the basis of unfamiliar object test

Abscissa: type of behavioral reaction 1 - exploratory (n=5), 2 - active defense (n=22), 3 - passive defense (n=10); 4 - "capitulation" reaction (n=3). Ordinate - number of animals: I - response recovered within 3 days; II - recovered on day 4-5; III - recovered on day 6 or after. \* animal with high level of thirst drive

## PAPERS:

P1266(28/90) Vorozhtsova SV, Gerasimenko VN.

***Cytogenetic damage to mammalian cells after exposure to charged particles with relativistic energy.***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; И Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume III Pushchino: USSR Academy of Sciences; 1989. Pages 562-563.

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

Genetics, Cytogenetic Damage, Corneal Epithelium, Lymphocytes

Mice, Humans

Radiobiology, Charged Particles, Relativistic Energy

**Abstract:** The authors studied damage to the chromosomal apparatus in cells of the corneal epithelium in mice and lymphocytes in human peripheral blood cultures after exposure to protons with energy of 9 GeV, helium and carbon ions with energy of 4.0 GeV/nuc in a dose range of 25-500 cGy.

The dose-response curve is initially linear up to a dose level of 100-250 cGy. After this point, when dose is increased, there is a change in the shape of the curve, with a "plateau" at different levels for different types of cells. Accelerated charged particles were observed to be more effective than  $\gamma$ -quanta. The RBE coefficient computed for the dose associated with formation of 50% aberrant cells in the cell populations studied changed within the limits of 1.4-2.8. When the irradiation dose increased, so did the number of chromosomal aberrations that developed. After irradiation with heavy charged particles, a greater number of chromosomal aberrations occurred, especially at high doses. This was most noticeable in the irradiation of lymphocytes of human peripheral blood, with a single cell containing as many as 13-15 sites of chromosomal damage.

A characteristic of the effects of the particles with relativistic energy that were studied is a high yield of translocation type aberrations (dicentric, rings, bridges, and chromatid exchange). The quantity of dicentric and ring aberrations in human lymphocytes that had been irradiated with protons and helium and carbon ions exceeded by a factor of 1.5-2 the level of paired fragments. In the corneal epithelium of mice the level of aberrant cells with bridges exceeded by a factor of 3-30 the number of cells with fragments, and the largest value of the ratio was obtained for radiation doses up to 250 cGy.

The RBE coefficient of charged particles, computed from results of various tests, changed as a function of cell type within limits of 1.4-2.7. Lower values of RBE coefficients were obtained for irradiation of lymphocytes.

P1261(28/90) Benevodenskiy VN, Kuznetsova IV.

***Methodological approach to determining the biological effects of heavy ions of galactic cosmic radiation.***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume IV Pushchino: USSR Academy of Sciences; 1989.

Pages: 994-995.

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Radiobiology, Biological Effects

Microbiology, Yeast Cells

Heavy Ions, Galactic Cosmic Radiation; Space Flight, COSMOS

**Abstract:** It is well known that the effects of heavy charged particles of galactic cosmic radiation represent a major hazard of long-term space flight. The physical properties of interactions of these particles with matter (their enormous energy, high LET, and certain other properties), despite their extremely low flux, may cause undesirable physiological effects. However, there is little direct experimental proof of the high biological effect of individual particles of galactic cosmic radiation or their ability to damage a large number of cells. This is primarily due to the virtual absence of methods for strictly quantitative measurement of the biological effects of single ionizing particles on single or small groups of cells. Classical methods of quantitative radiobiology, based on the study of the reactions of large populations of cells irradiated with a relatively high dose, are not applicable here. Thus it becomes necessary to develop special techniques for qualitative and quantitative assessment of the biological effects of heavy ions of galactic cosmic radiation for use in flight experiments.

The goal of this work was to develop biological models allowing the assessment of the dangers of this type of radiation starting with the actual pattern of cosmonaut irradiation. The model was based on the method of quantitative and qualitative computation of radiation damage to yeast cells.

As a result of the research two methodological approaches were developed:

1. Estimate of the number of damaged cells in a given small volume simulating certain unique portions of human tissue (for example, the brain). For this purpose, colonies of yeast cells of varying size were used, each containing a varying number of cells.
2. Estimate of the amount of radiation damage to individual dividing cells, based on analysis of their lineage.

To solve the first problem, a large scale study was conducted to develop a methodology for including colonies of yeast cells in a biophysical assembly.

Solution of the second problem required improvement of existing methods for rapidly obtaining a large number of lineages of the division of individual cells. A special apparatus was therefore developed to simultaneously record the division kinetics of a large number of cells.

The first of the biological models developed for estimating radiation damage from heavy ions of galactic cosmic radiation was used in flight experiments on COSMOS series biosatellites. These studies made it possible to evaluate the limit and mean number of cells sustaining damage of varying degree in the area through which individual particles of galactic cosmic radiation passed (biological effective radius of their tracks).



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Using the second method, a large amount of information was generated that made it possible to evaluate the extent of radiation damage to individual cells on the basis of their division lineage during the first five generations. A number of characteristics of the lineages were identified that provided most information on the damage sustained by the initial mother cell.

P1262(28/90) Kabachenko AN, Fedorenko BS, Portman AI.

***Cataractogenic effectiveness of accelerated charged particles of high energy.***

In I Vsesoyuznyy S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume V

Pushchino: USSR Academy of Sciences; 1989.

Pages: 1193..

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Radiobiology, Cataractogenesis

Mice

Accelerated Charged Particles, High Energy

**Abstract:** Cataractogenesis was studied in SVAxC57Bl6 hybrid mice subjected to whole-body radiation with helium ions with energy of 4 GeV/nucleon, protons at 9 GeV, and carbon ions with energy of 300 MeV/nucleon (LET=0.88, 0.23, and 12.0 keV/μm, respectively). <sup>60</sup>Co (LET=0.3 keV/μm) was used as a standard of comparison. Doses of protons, helium ions and γ-radiation ranged from 0.5-6.0 Gy, and dose for carbon ions ranged from 0.03-0.5 Gy. Dose rate of helium ions was 0.002 Gy/sec., of protons 0.002 Gy/sec., of carbon ions 0.0903 Gy/sec., and of γ-radiation 0.006 Gy/sec. Mice were examined without anesthesia using an electroophthalmoscope immediately before irradiation and every 4 weeks subsequent to it. The pupils were dilated with a 1% solution of homatropine. The animals were observed throughout their life-spans.

The results of this research showed that all irradiated animals developed lenticular opacities after a latent period, which varied as a function of type and dose of radiation. In animals irradiated with helium ions and protons in a dose of 4 Gy, the duration of the latent period was 4 weeks, and for doses of 1-2 Gy it was 8 weeks. After irradiation by carbon ions at doses of 0.01-1.0 Gy, the first lenticular opacities were detected after 6 weeks. The duration of the latent period for development of lenticular opacity after γ-irradiation was 10-15 weeks for irradiation in doses from 1 to 4 Gy. The first age-related lenticular opacities occurred in control animals 19-20 weeks from the beginning of the experiment. As time after irradiation increased, frequency of lenticular opacity grew and reached 100% at various times, which varied as a function of dose magnitude and type of radiation.

The dose-response function in the dose ranges used can be described by a saturation curve for high-energy charged particles, while for γ-irradiation the curve was linear. The RBE coefficients of the radiation studies, computed for the 50% effectiveness level, varied as a function of time elapsed since irradiation from 1 to 2.7 for helium ions and protons, and from 4.2 to 30.4 for carbon ions

P1263(28/90) Fedorenko BS.

***Carcinogenic effectiveness of accelerated charged high energy particles.***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume V Pushchino: USSR Academy of Sciences; 1989.

Pages: 1223-1224.

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Radiobiology, Carcinogenesis

Rats, Females

Charged Particles, High Energy

**Abstract:** The carcinogenic effectiveness of protons with energy of 645 MeV and 9 GeV, and also of helium ions of 4 GeV/nucleon and  $\gamma$ -radiation from  $^{60}\text{Co}$ , was studied in outbred female rats and rats (gender not specified) of the Wistar line, 4 months old. The animals were subjected to whole-body irradiation in a single dose varying from 0.25 to 4.0 Gy. Dose rates were 7.5, 2.0, 2.0, and 5.5 cGy/sec. Observation of the animals continued until their deaths. The frequency, onset time, and histological structure of neoformations were recorded. The effects of all forms of radiation led to a decrease in the latent period for development of tumors compared to nonirradiated animals. The peak frequency of tumors at any site in the body and leukopenia in nonirradiated rats occurred during the last 1/4 of the life-span, while in irradiated rats it occurred in the middle of the life-span. Increase in frequency was observed for tumors of the breast (up to 36.4-50.0% with irradiation doses of 0.25-4.0 Gy), pituitary adenoma (to 44.8-65.45), tumors of the thyroid and parathyroid glands, adrenal glands, visceral organs, skin, and subcutaneous tissue, as well as leukemia. The dose-response curves for tumors of various organs differed in shape. Analysis supported a conclusion that the curves were all segments of the same S curve, which reflects the complexity of the function linking radiation dose and biological effect. Estimate of the carcinogenic risk using approximations of the dose response curves and log normal functions based on criteria for "risk dose" showed that the risk of developing breast cancer after a single dose of  $\gamma$ -irradiation is equal to  $10^{-4}$  for the entire life-span and a dose of 0.25 Gy, while the risks are  $10^{-5}$  and  $10^{-6}$  for doses of 0.19 and 0.15 Gy, respectively. The same levels of risk are associated with protons with energy 645 MeV in doses of 0.11, 0.08, and 0.05 Gy; helium ions in doses of 0.014, 0.007, and 0.004 Gy; and protons of 9 GeV at doses of 0.017, 0.010, and 0.06 Gy. Thus, if an acceptable risk of developing a tumor is defined as  $10^{-4}$  for the entire life-span, then the acceptable dose of irradiation with helium ions would be 0.014 Gy. The RBE coefficients of radiation, computed nonparametrically, decreased with increasing doses of radiation. In particular for helium ions after 540 days,  $\text{RBE}_{\text{max}}=8$  (at a dose of 0.25 Gy) and  $\text{RBE}_{\text{max}}=1$  (with a dose of 4.0 Gy). Critical frequencies of tumors of the adrenal, pituitary, thyroid, and mammary glands and soft tissue for protons of 645 MeV, were  $\text{RBE}_{\text{max}}=4.0$ , 4.0, 2.0, and 0.5, respectively, after irradiation in a dose of 1.0 Gy. This means that with respect to risk of developing a tumor the adrenal, pituitary and thyroid glands are more sensitive to protons than to  $\gamma$ -radiation.

P1264(28/9) Vladimirov VG, Krasil'nikov II.

***Radioprotectors and the theory of the radioprotective effect.***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume III Pushchino: USSR Academy of Sciences; 1989.

Pages: 695-697.

Authors' affiliation: S.M. Korov Academy of Military Medicine

Radiobiology, Radioprotective Effect

Theoretical Article

Radioprotectors

**Abstract:** The results of development of chemical agents to increase the radiation resistance of the body demonstrates current limits on the effectiveness and scope of the radioprotectors (radioprotective receptors). Further progress in this area of research, undoubtedly will be determined by the state of theoretical development of the problem of antiradiation protection.

A number of already known and new factors which are not covered by the old hypotheses allow us to pose the question of the creation of a general theory of radioprotective effects. Such factors include:

- the huge variety in chemical structures of substances with radioprotective effects
- the possibility of increasing radioresistance using not only chemical, but physical and biological factors
- the existence of some substances that not only have radioprotective properties, but, under some conditions radiosensitizing properties as well
- the existence of variations in the effectiveness of substances from one biological species to another
- the positive correlation between the radioprotective activity of substances and their capacity to increase overall nonspecific resistance of the organism
- the absence of special receptors developed in the course of evolution for sensing the effects of ionizing radiation.

The level of the radioprotective effect is determined by the properties of the radioprotector and the biological system. Here, radioprotectors are analogous to typical medicinal substances. In other words, the radioprotective effect should be considered the result of a primary pharmaceutical reaction and secondary reactions of the body to the chemical compound used.

Three stages may be distinguished in the development of the radioprotective effect. The first is highly specific and determined by specific chemical groups of the molecules of the radioprotectors and the appropriate receptor molecules. This is the primary pharmacological reaction at the atomic-molecular level. It involves the interaction of the substances and the biological structures being protected, and also the transmission of a certain quantity of information to the biological system.

The second stage is relatively specific and is already associated with the gradual transformation of the primary pharmacological reaction into a set of universal nonspecific secondary reactions with general biological significance. This stage is based on the biochemical changes occurring in the cells and tissues (inhibition of biosynthesis of DNA, stimulation of the system of cyclic nucleotides and antioxidant system, changes in bioenergetics, etc.).

The third stage is represented by biological, nonspecific reactions (quantitative and qualitative change in the cellular pool of radiosensitive tissues, changes in migrational activity of stem cells, entry of cells into the radioresistant phase of the mitotic cycle, decreased oxygen consumption, etc.).

The nature of the secondary reactions allows consideration of the overall radioprotective effect as a nonspecific phenomenon and makes it expedient to look for radioprotectors in new classes of chemical substances, which are not structurally related to each other. In this respect, radioprotectors are analogous to substances called "biological depressants," the biological activity of which is not associated with chemical structure. The disruption of the structural and functional sequences of biological systems at the cellular level ("biochemical cellular shock," "nonspecific reaction of cells") induced by radioprotectors prevents transmission of the harmful effects of radiation at one level of the system to another. The reversible nature of this phenomenon is an important condition for the realization of the radioprotective effect. For this reason it would seem prudent to use antagonists that negate the primary and secondary responses to the radioprotector during the postirradiation period.

The concepts presented above explain why substances that are extremely different in structure support radioprotection at a certain level and no higher. In the next stages, the reserves of specificity, determining the primary pharmacological reactions to the radioprotector, would seem to be exhausted. Evidently this is the reason for the disappointing results of the extensive search for more effective radioprotectors based on new principles. Substantial progress may be anticipated only when screening is combined with other research directions that take account of the secondary reactions of biosystems in realizing the radioprotective effect.

P1265(28/9) Morozova IN. Lukashin BP.

***Prospects for using immunomodulators as a means to increase nonspecific resistance in radiation pathology.***

In: I Vsesoyuznyy Radiobiologicheskii S"yezd; I Всесоюзный Радиобиологический Съезд (I All-Union Radiobiology Congress) Moscow 21-27 August, 1989. Paper Abstracts. Volume III Pushchino: USSR Academy of Sciences; 1989.

Pages: 743-744.

Authors' affiliation: S.M. Korov Academy of Military Medicine

Radiobiology, Nonspecific Resistance,  $\gamma$ -Irradiation

Mice, Rats

Immunology, Immunomodulators, Alanine

**Abstract:** One of the promising directions in the development of medical means of protection against the damage caused by penetrating radiation is the search for antiradiation agents among endogenous compounds and their synthetic analogues, some of which have radioprotective and therapeutic actions.

The goal of this research was to study prospects for using derivatives of alanine — quateron (possibly,  $\alpha,\beta$ -Dimethyl- $\gamma$ -diethylaminopropyl ester para--butoxybenzoylbenzoic acid, a ganglioblocker) and leakadin (chemical composition unknown) — as agents to increase nonspecific radioresistance. In all experiments the drugs were administered intraperitoneally.

Experiments were performed on outbred mice, mice of the BALB/C line, and outbred rats. Experimental animals were subjected to  $\gamma$ -irradiation in doses of LD<sub>90/30</sub>. The radioprotective effects of quateron and leakadin were studied in a multifactor experiment, which made it possible to determine the optimal conditions for their use. It was established that quateron has its maximal radioprotective effect when administered in a dose of 750 mg/kg 1 day before irradiation, and leakadin in a dose of 1000 mg/kg 2 days before irradiation. Under these conditions, the survival rate of the experimental animals increased reliably by 30-40% compared to the irradiated control. Both drugs were most effective for mean lethal doses of radiation, which is characteristic of radioprotective agents working through the mechanism of increased nonspecific resistance.

With the goal of establishing in more detail the mechanisms through which radio resistance is increased by quateron and leakadin, their effects on the hemopoiesis system and certain parameters of nonspecific resistance were studied. It was established that quateron and leakadin under conditions of exposure to radiation decrease destruction and increase rate of recovery of cell density of bone marrow, increase the number of endogenous colonies in the spleen, and increase the number of colony forming units in bone marrow. These effects occur at the moment of exposure to radiation, evidently enhancing capacity to ameliorate severity of postradiation depression of hemopoiesis.

The corrective effect of quateron and leakadin on immune status in an irradiated organism was established. Under conditions of acute damage to the immune system from exposure to ionizing radiation, the drugs studied substantially attenuated the severity of decreases in antibody formation. It was established that under certain conditions quateron and leakadin may affect the direction of differentiation of stem cells so that more immunocompetent cells are produced.

When the functional activity of the cells of the reticuloendothelial and bactericidal systems of neutrophilic granulocytes is severely depressed, introduction of the drugs leads to normalization of pathological impairments.

Thus, the research performed provides grounds for concluding that the radioprotective properties of quateron and leakadin may result from their stimulating effect on the colony-forming capacity of bone marrow cells and attenuation of the depressive effect of irradiation on factors of anti-infection resistance of the irradiated organisms.

On the whole, this work shows that quateron and leakadin show promise for use as agents increasing resistance to radiation.

P1250(28/90)\* Yablontsev NN.

***Documents setting standards for radiation safety for space flight.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 55;1990.

[8 references; none in English]

Radiobiology, Radiation Safety Standards

Humans, Cosmonauts

Space Flights, Long-Term

**Abstract:** In 1985 the Soviet government set new standards for radiation safety on space flights. One document set safety standards for flights of up to 3 years and the other provided methodological guidelines for computing individual radiation dose of cosmonauts accumulated during the stages of selection and training for space flight. According to the new safety standards for flights lasting up to 3 years, the maximum acceptable occupational dose should not exceed 4 Sv. This dose is composed of irradiation during space flight and radiation exposure during medical examination using X-rays that can be computed from a special chart based on the methodological guidelines. However, these two documents were contradictory, making it impossible to compute occupational dose. The problem was that the guidelines did not provide values for whole-body doses, just individual organs. To eliminate this problem the International Commission on Radiation Protection proposed using the concept of effective equivalent dose, which defines the dose of homogeneous whole-body irradiation corresponding to the risk of appearance of stochastic effects for the organ dose actually received. A table of weighting factors is provided to find this equivalence.

Values of weighting factors for computing equivalent doses

Organs	$W_t$
Reproductive organs	0.25
Mammary glands	0.15
Active bone marrow	0.12
Lungs	0.12
Stomach	0.06
Pancreas	0.06
Liver	0.06
Kidneys	0.06
Spleen	0.06
Thyroid	0.03

Note:  $W_t$  - is the weighting factor describing the risk of occurrence of stochastic effects in humans after irradiation of an organ or tissue.



P1284(28/90)\*\* Minkova M, Pantev B (Bulgaria)

*The effects of combined physical and chemical radiation protection under conditions of simulated hypergravity.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 60-61;1990.

[9 references; none in English]

Radiobiology, Radioprotectors, Physical/Chemical

Rats

Acceleration

**Abstract:** Subjects in this experiment were male Wistar rats, divided into the following groups: 1 — irradiation with shielding; 2 — acceleration; 3 — acceleration and irradiation; 4 — acceleration, irradiation and adeturon (a radioprotective substance, chemical composition unknown). Local protection of the abdominal-lumbar region was achieved through use of lead bands 2.5 mm thick that attenuated dose by 28-30% for the shielded tissues and organs. Acceleration of +5 Gx lasting 5 minutes was achieved through centrifugation. One hour after acceleration the animals were irradiated at a dose of 2 Gy with  $^{137}\text{Cs}$ . Fifteen-20 minutes before irradiation, adeturon was administered intraperitoneally in a dose of 50 mg per 1 kg body weight, which is 1/17 the LD<sub>50</sub> and 1/6 the optimal dose. Joint effects of radiation protection were studied 1, 3, and 10 days after irradiation. Parameters investigated were weight and cell density of the spleen, bone marrow and small intestine. The number of nucleated cells of bone marrow and small intestine were counted in segments taken from the same area of the diaphysis and small intestine in an area 1 cm<sup>2</sup>. Data from 10 animals were obtained for each experimental observation and statistically analyzed using Student's t.

One day after acceleration the number of nucleated cells increased to 120% of the norm, normalizing 10 days later. Animals partially shielded by lead and irradiated showed moderate hypoplasia followed by increase of cell content of the bone marrow to 150% normal. Combined effects of acceleration and irradiation led to a significant depletion of the cell pool of bone marrow, reaching a maximum (up to 21%) on day 3 after treatment, without complete recovery subsequently. Administration of adeturon had a beneficial effect during the early postirradiation period, but did not facilitate repopulation of bone marrow. On day 10 after treatment animals receiving adeturon, acceleration, and irradiation did not differ from those shielded and irradiated. Acceleration increased spleen mass. Irradiation with shielding halved spleen weight. Combination of acceleration and radiation with shielding resulted in a spleen mass intermediate between acceleration alone and radiation alone. Addition of adeturon did not modify this effect. Effects on spleen cell density were analogous to those on weight, except for greater early hypoplasia when subtotal radiation and acceleration were combined. Adeturon did not have a marked modifying effect. Acceleration first decreased and then increased cellular density in the small intestine. Animals undergoing subtotal irradiation alone showed moderate hypoplasia followed by complete recovery. Animals for which acceleration and radiation were combined displayed greater hypoplasia, followed by only incomplete recovery. Addition of adeturon only served to further deplete the cell pool.

Results are interpreted as showing that under exposure to hypergravity, radioprotective effects of adeturon are attenuated and further exacerbate the effects of acceleration on the intestine. Shielding is suggested as a better protection for cosmonauts of necessity exposed to both radiation and acceleration.

Figure: Change in cell density of the bone marrow, spleen weight and cell density of the small intestine in rats after various types of treatment

## REPRODUCTIVE SYSTEM

### PAPERS:

P1237(28/90)\* Kokoreva LV, Chuvpilo TA, Pustynnikova AM.

*The effect of a high intensity magnetic field on the reproductive function of male rats.*

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(1): 28-30;1990.

[8 references; 1 in English]

Reproductive System, Reproductive Function (Male), Developmental Biology

Rats, Male

Radiobiology, Magnetic Field, High Intensity

**Abstract:** Two experiments were performed. In the first, male rats were subjected to a single 3-hour exposure to a constant magnetic field of induction of 0.4 T. In the second experiment, male rats were exposed to the same field throughout the spermatogenesis cycle for 56 days for 3 hours per day. The magnetic field, induced by an electromagnet at the central area of the interpole space, was virtually homogeneous, and inductance increased by 15-20% in the remainder of the field. Subjects were sexually mature Wistar rats. A total of 40 males and 120 females were used in experiment one (half in a control group) and 12 males in the experimental and 12 in the control groups for experiment 2. Immediately after exposure to the magnetic field, the untreated females were placed in the cage with a male; when one female became pregnant it was replaced with another. A total of 60 females were mated with control males and 64 with experimental males. Breeding occurred over a 7-day period. Pregnancy was determined through daily vaginal smears. The number of females inseminated on days 1-3 and 4-7 was calculated as a parameter reflecting male sexual activity. The number of impregnated females was used as a parameter indicative of the fertility of gametes. After the breeding period, the males were decapitated and the tail of the epididymis studied to determine functional state of spermatozooids. Some of the females were sacrificed on day 21 of pregnancy and the numbers of implantations and resorptions, total fetal death rate, number of live embryos, their weight, placental weight, and fluid content of fetal tissue and placentae were measured. On the day the females gave birth, pregnancy duration, numbers of live and dead neonates, their weight, and sexual composition of the litter were determined to provide information concerning the genetic potency of the spermatozooids. Development of the neonates was observed throughout the first month of life. Soft tissues and visceral organs were investigated by an undescribed method and possible deviations in skeletal development also assessed.

In experiment 1, no differences in insemination or impregnation were observed between experimental and control animals. In experiment 2, a single experimental animal failed to inseminate a single female, but group differences were not significant. Of 48 females inseminated by experimental males, 42 (87.5%) were impregnated while 43/45 females (95.6%) were impregnated by control males. On day 21 of pregnancy no difference was noted between offspring of control rats and those of experiment 1 experimental rats. Embryonal death rate was elevated in offspring of experiment 2 experimental rats, attributable to preimplantation deaths (165% of control) and total embryonal deaths (146% of control). No differences were observed in weight, hydration or physiological maturity of embryos in either experiment. No significant differences were observed in general status of neonates, their visceral organs, or bones. When early postnatal development was observed, experiment 1 experimental rats appeared to display accelerated development, possibly attributable to initial developmental retardation. No differences were found in experiment 2. Analysis of spermatozooids revealed a slight decrease (to 88.6% control) in the total number of spermatozooids in experimental animals in the second study. No differences were found in any other parameters.

## REPRODUCTIVE SYSTEM

The authors conclude that mature spermatozooids are resistant to a single exposure to a constant magnetic field and that this factor does not lead to mutations in gametes decreasing fetal viability or disrupting development. The slight but significant increase in preimplantation deaths of offspring of males repeatedly exposed to the field may suggest increased frequency of dominant lethal mutations in gametes of treated males.

Table: Parameters of fetal development of offspring of untreated females bred with males exposed to single and 56 exposures to constant magnetic field (0.4 T)

Figure: Embryonal death rate of offspring of male rats exposed once and repeatedly to a constant magnetic field (0.4 T)

### PAPER:

P1267(28/90)\*\* Gazenko OG, Grigor'yev AI, Yegorov AD.

***Medical investigations of long-term manned space flight on-board Salyut-7-Soyuz-T.***

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(2): 9-15; 1990.

[11 references; 13 in English]

Space Medicine, Operational Medicine, Cardiovascular and Respiratory Systems, Body Fluids, Musculoskeletal System, Motor Coordination, Bones, Muscle Mass, Neurophysiology, Vestibular System, Sensory Systems, Endocrinology, Nutrition, Human Performance

Humans, Cosmonauts

Space Flight, Salyut-7, Long-Term, EVAs, Prophylactic Countermeasures, Exercise, LBNP

Abstract: Six long-term prime crew flights (211, 150, 237, 112-168, 65, and 125 days) were completed on the Salyut-7-Soyuz complex. In addition, there were five short-term (8-12 days) visiting crew flights, including two international flights with France and India. A total of 21 cosmonauts worked on Salyut-7, with three completing two flights and one completing three. A total of 2208 man-days were spent in space. Seven cosmonauts spent more than 130 days in space, while L.D. Kizim and V.A. Solovyev each totalled 361 days. There were a total of 13 EVAs, lasting a total of 97 man hours. Kizim and Solovyev each completed 8 EVAs for a total of 31 hours 40 minutes each in the vacuum of space. V.A. Dzhanibekov and V.P. Savinykh had to "bring the station back to life" after a disruption of electrical supply, and successfully completed this task. Medical objectives of the Salyut-7-Soyuz-T program consisted first and foremost of maintaining the health and performance level of the crews through environmental and medical monitoring (including diagnostic examinations), and a set of prophylactic measures to prevent the effects of weightlessness. A broad range of medical investigations were performed on the station, directed at accumulating of further information about physiological responses to short- and long-term flights, more in-depth study (through participation of a physician-cosmonaut) of acute adaptation to weightlessness, physiology and mechanisms of changes in hemodynamics. During the flight of the crew that included a physician, echocardiography and biochemical studies were performed and the vestibular system and the interactions of a number of sensory systems were studied.

Microclimate parameters and properties of the cabin atmosphere were maintained in the optimal range approximating conditions on Earth. Comparative analysis of the thermal sensations of crewmembers and microclimate parameters revealed some complaints of feeling "cold" or "cool" in all crewmembers, suggesting moderate strain on thermal regulation when temperatures were below 19°C and relative humidity above 60%. Conditions were evaluated as "good" and "comfortable" when cabin temperature was 22-24°C.

Cosmonaut rations were specially developed for the Salyut-7 crews and contained mainly freeze-dried products. Crews are less likely to tire of such a diet than one consisting of canned, sterilized products. Menus were planned on a 6-day cycle and utilized the menu-selection system developed for Salyut-7 and consisting of 75 product designations. The daily ration was balanced for all the essential ingredients. Mean daily calorie content was 3150 calories with 145.0 g protein, 120.0 g fat, 386.0 g carbohydrates, 0.9 g calcium, 3.8 g potassium, 6.1 g sodium, and 50 mg iron. The crew was supplied with stored water, as well as water produced by a regeneration system utilizing condensate of atmospheric moisture. Water consumption varied from 1.6 to 2 l per person per day, and included water in the food and metabolic water totalled 2.5 to 2.9 liters.

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The daily work-rest schedule stipulated 8-9 hours of sleep, 8 hours 30 minutes of work, and 2 hours of exercise, with 2 days off each week. When visiting crews were on the station, plans called for synchronization of the schedules of both crews. Days in which both crews worked together were marked by the greatest amounts and rate of work. During these periods, there were episodes in which cosmonauts suffered from too little sleep.

The system of prophylactic countermeasures was used only by prime crews. These measures included daily exercise on the bicycle ergometer and treadmill with a vertical force of 60 kg exerted by the loading suit, and a system of bungee cords and straps and long-term (10 hours/day) wearing of loading suits. Loading suits were worn to maintain conditioning of the most important systems, activate venous pumping and peripheral muscle pulsation, and stimulate certain groups of receptors. During the last stage of the flight lower body negative pressure was applied and immediately after reentry special prophylactic suits were worn to diminish blood redistribution that had occurred in weightlessness and in the period of readaptation to the Earth's gravity, and also to simulate neuro-reflex mechanisms regulating circulation in a vertical position. Fluid status in the body was regulated through use of fluid-salt supplements during the last days of the flight. Exercise sessions occurred once or twice a day on a 4-day cycle (3 days on and 1 day off) with periods of decreased and increased loading. In a number of cases (for example while they were working with the visiting crew), exercise sessions decreased significantly in duration or were not held at all. The structure and sequence of exercises in each session was tailored for each cosmonaut.

All cosmonauts reported that they felt well throughout the flight. The sensation of head fullness, pronounced at the beginning of the flight, gradually diminished and usually had virtually disappeared by day 7-9. In some instances it only disappeared completely after 1.5 months in space, but even then it did not affect performance. A number of cosmonauts developed vestibular discomfort at the beginning of flight, which varied in severity. All cosmonauts retained their appetites. Natural functions were normal. No cosmonauts displayed signs of inadequate psychological adaptation and were able to perform their work successfully. All were highly motivated to perform their assigned tasks well and on time. Intragroup cohesion remained stable at a high level. Performance was relatively high. During isolated periods, especially when workload was high and after joint work with a visiting crew, cosmonauts noted fatigue and elements of moodiness and debilitation, which were alleviated by optimizing the work-rest schedule. Sleep periods lasted for 7-8 hours and were rated by cosmonauts as adequate for their needs. At the landing site and during the immediate postflight period, the state of the cosmonauts was qualitatively no different from that after Salyut-6 flights. After the 211- and 237-day flights signs of disrupted motor coordination and certain other symptoms may have been somewhat more severe, and two cosmonauts lost more weight than had previously been observed (maximum of 7.7 kg).

Greatest amount of weight lost (in a single month) occurred in the third months of the 211-day flight (-6.2 kg) and 237-day flight (-5 kg). However, one cosmonaut lost -6.3 kg in the first month of the 168-day flight, but subsequently regained some of it. In the other cosmonauts maximal weight loss varied from -1.3 to -4 kg. Some cosmonauts either maintained or gained weight. Calf volume began to decrease during the initial days of flight. Subsequently calf volume generally continued to decrease at a decreasing rate for the next 1-2 months and then stabilized. However, some cosmonauts continued to lose calf volume throughout the flight. Maximal loss of calf volume on the long-term flights varied from 8-20%.

Subjective symptoms of motion sickness were reported by 8 of the 19 subjects. During the initial period of adaptation to weightlessness under conditions of rest, changes in vestibular function and vestibulo-oculomotor interactions were noted. The decrease observed in the vestibular threshold for nystagmus suggested increased dynamic excitability of the canal

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system. The inhibition of the tracking function at rest may be evaluated as a sign of decreased static vestibular excitability.

Postflight research indicated that weightlessness had a substantial effect on all components of motor activity from muscles to the system of motor regulation: strength of flexor and extensor muscles of the thigh and calf decreased; response to stimulation of the contact surface of the foot increased and the threshold and maximal amplitude of the T-reflex decreased; postural stability decreased; threshold of loss of balance in response to disruptive forces decreased; accuracy of programmed movements decreased. The severity of these changes depended both on flight duration and amount of prophylactic countermeasures.

Cardiac response to space flight involved a mild tendency for heart rate to increase (from mean of 64 to mean of 68 beats/minute). No changes occurred in cardiac stroke volume. There were signs of increased stress on the heart (shortening of hemodynamically ineffective left ventricle isometric contraction and relaxation phases and increase in the ejection time and rapid filling phase).

Electrocardiographic data (leads I-III,  $v_1$ - $v_6$ ) revealed maintenance of the sinus rhythm, appearance of isolated rare monotonic systoles in some cosmonauts, tendency (remaining in the range of preflight fluctuations) for AV conduction to increase, total QRS amplitude to decrease slightly and for T wave amplitude to decrease significantly in a diffuse manner. Only one cosmonaut displayed a change in the configuration of T waves in the form of a transitory double peak and a two-phase pattern.

In general the EKGs of all cosmonauts were within normal range and retained their individual features. Changes in bioelectric activity of the myocardium were also observed in other long-term flights and probably were due to the positional and neurohumoral shifts, changes in hemodynamics, and also metabolic changes in the myocardium.

When cosmonauts performed tests with graded physical exercise there was a decrease in the absolute magnitude of stroke volume, and an increase in heart rate contribution to cardiac output, greater shortening of the isometric contraction phase, ejection time, and rapid filling phase (compared to exercise response preflight).

Echocardiographic studies performed on two cosmonauts at rest on the 237-day flight and during graded physical exercise revealed decrease of left ventricular end-diastolic and end-systolic volumes and also of stroke volume and cardiac output (only during exercise), compared with analogous preflight data. High parameters of myocardial contractility (ejection fraction and rate of circumferential shortening of fibers) in response to exercise in flight, despite the decrease in stroke volume, made it possible to assess the functional state of the myocardium in both cosmonauts in flight as satisfactory.

In response to application of LBNP during months 2-8 of flight, the increase in heart rate and decrease in circulatory volume were virtually the same as preflight. The absolute values of stroke volume and cardiac output in flight in response to LBNP were either unchanged or exceeded preflight responses.

There was a tendency for end-systolic pressure to increase (by a mean of 5 mm Hg) and diastolic pressure to decrease (mean of 3-7 mm Hg). Pulse pressure increased by 5-7 mm Hg. In response to exercise, absolute values of diastolic mean, and true systolic pressure decreased in flight compared to preflight exercise responses by 6-12 mm Hg, while pulse pressure increased by up to 7 mm Hg. In response to LBNP in flight there was a decrease of diastolic and an increase in true systolic and end-systolic, while mean pressure was unaltered.

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Inflight, the pattern of pulsed blood filling and vascular tonus throughout the body altered. Pulsed blood filling of the calves decreased considerably; there was an increase in tonus of the large vessels of the forearms and a marked decrease in tonus of small vessels of the forearms. This was different from results on Salyut-6 in which pulsed blood filling of the forearms showed a constant tendency to increase, while tonus of large vessels of the forearms and calves decreased. Like results on Salyut-6, there was a tendency for differences in arm and leg parameters of pulsed blood filling present on Earth to decrease, evidently due to diminished pressure gradients in weightlessness. In the area of the head (basin of the internal carotid artery) pulsed blood filling of the right and left hemisphere showed a weak tendency to decrease. Tonus of small vessels increased on the left during month 1 of flight and subsequently increased markedly on the right and left compared to preflight values. A number of studies recorded venous waves, which indirectly indicate impeded venous outflow from the head. Signs of vasodilation of small vessels in the basin of the internal carotid arteries may result from a reflexive adaptive reaction of the cardiopulmonary area to increased blood volume and pressure, which serves to improve blood flow and prevent further decrease in venous congestion.

Research performed in months 2-3 of the flight of prime crews 3 and 4 revealed a decrease in urinary concentration of the majority of electrolytes, total osmotically active substances, calcium-to-magnesium ratio, and sodium-to-potassium ratio, as well as of concentration of creatinine and urea and antidiuretic hormone (ADH) in urine. Aldosterone and hydrocortisone concentrations decreased in month 2 and increased in month 3. In month 8, both cosmonauts studied revealed decreased renal excretion of sodium and one also showed retention of fluid and potassium. During this same period, there were signs of activation of the mineralocorticoid function of the adrenal cortex, manifested as increased renal excretion of aldosterone and increased synthesis as revealed by decreased excretion of 11-desoxocorticosterone and increased plasma renin activity. Renal excretion of ADH on days 216-219 of flight increased along with a tendency to decrease in blood. On days 43-45 and 86-88 during the 5-month flight, ADH in urine decreased. Increased renal excretion of ADH as flight duration increases may be associated with diminished sensitivity of the kidneys to this hormone.

During flight, blood hydrocortisone increased, while concentration of desoxyhydrocortisone remained unchanged. Excretion of these hormones was also unchanged. Renal excretion of products of catecholamine metabolism (homovanillic and vanillylmandelic acids, normetanephrine and metanephrine) decreased.

After long-term flights, researchers observed shifts in blood electrolytes in the form of decreased levels of potassium and some increase in sodium, chlorine and osmotically active substances. Concentration of total calcium and especially its ionized fraction exceeded preflight levels by 16-32%. On day 7 postflight blood electrolytes approached the norm with the exception of total calcium and its ionized fraction.

On the whole, recovery of fluid-electrolyte homeostasis during the early postflight period was accompanied by a compensatory retention of fluids, monovalent ions, and osmotically active substances serving to restore appropriate circulatory homeostasis. Changes in volume of bivalent ions postflight were more stable and were evidently associated with metabolic shifts at the tissue level.

The postflight period was characterized by changes in hormonal status in the form of sharp increases in production and renal excretion of ADH and to a lesser extent aldosterone, and activation of the sympathetic adrenergic, cholinergic, and histaminergic systems, with decreased activity of the serotonergic system.

## SPACE MEDICINE

Computer tomographic examination of bones of eight cosmonauts before and after long-term space flights revealed a decrease in mineral saturation of the lumbar vertebrae of 11% in one subject after a 150-day flight. After the 237-day flight, mineral density of the leg bones (measured using photon absorptiometry) decreased by 7% in one cosmonaut. The data failed to reveal substantial changes in mineral density of bone tissue after long-term flights.

There is a decrease in reactivity of T-lymphocytes and also a significant decrease (in five of six cosmonauts studied) in the functional activity of T-helpers, suggesting changes in the regulatory component determining the strength and appropriateness of the immune response. The decrease in the functional activity of natural killer lymphocytes and changes in the receptor apparatus of these cells suggest changes in antiviral resistance. Decreases in the most important lymphokines — interleukin-2 and endogenous interferons of the  $\alpha$ - and  $\gamma$ -types — were noted in one crew. Levels of A-, G-, and M-immunoglobulins were not generally altered. Changes tended to normalize within 7 days, although suppressor activity required 1.5-2 months to return to normal. The authors state that the disruption of effector functions may be associated with changes in the regulatory populations of immunocompetent cells.

Physiological parameters during EVAs were close to those observed during training in the underwater laboratories and thermal chamber. It was found that when repeated EVAs are performed by the same cosmonaut, physiological cost decreases. Successful performance of EVAs at points in flight ranging from several days to 6 months; and the absence of any major difference in response suggest that in principle EVAs can be performed at any time during a flight. Decompression sickness was prevented by 25-30 minutes of oxygen breathing in the airlock and maintenance of high absolute pressure in the suit of 300 mm Hg.

The authors conclude that there were no changes observed in cosmonauts after flights on Salyut 7 that were qualitatively different from those observed before. Physiological changes were functional in nature. After the flights, cosmonauts were judged to be in satisfactory condition, although after the longer flights their functional capacities were somewhat diminished. All functions recovered completely during readaptation. Thus, prophylactic measures were effective.



# SPACE MEDICINE

Table: Manned flights performed in the USSR during 1982-1986 on Salyut-7-Soyuz-T

Crew	Cosmonaut	Year of Birth	Flight Dates	Flight Duration
Prime	A. N. Berezevoy	1942	5/13/82-12/10/82	211 days 9 hrs
	V.V. Lebedev	1942		
Visiting (USSR/ France)	V.A. Dzhanibekov	1942	6/24/82-7/2/82	7 days 22 hrs
	A.S. Ivanchenkov	1940		
	J.L. Chretien	1938		
Visiting	L.I. Popov	1945	8/18/82-8/27/82	7 days 22 hrs
	A.A. Serebrov	1944		
	S.Ye. Savitskaya (Female)	1948		
Prime	V.A. Lyakhov	1941	6/27/83-11/23/83	149 days 10 hr
	A.P. Aleksandrov	1943		
Prime	L.D. Kizim	1941	2/8/84-10/2/84	236 days 23 hr
	V.A. Solov'yev	1949		
	O.Yu. Atkov	1949		
Visiting (USSR/ India)	Yu. V. Malyshev	1941	4/3/84-4/11/84	7 days 22 hrs.
	G.M. Strekalov	1940		
	R. Sharma	1949		
Visiting	V.A. Dzhanibekov	1942	7/17/84-7/29/84	11 days 19 hrs
	S.Ye. Savitskaya	1948		
	I.P. Volk	1940		
Prime	V.A. Dzhanibekov	1942	6/6/85-9/26/85	112 days 2 hrs
	V.P. Savinykh	1940		
Prime	V.V. Vasyutin	1952	9/17/85-11/21/85	64 days 22 hrs
	G. M. Grechko	1931	9/17/85-9/26/85	8 days 21 hrs
	A.A. Volkov	1948	9/17/85-11/21/85	64 day 22 hrs
Prime	L.D. Kizim	1941	3/13/86-7/16/86	125 days
	V.A. Solov'yev	1946		

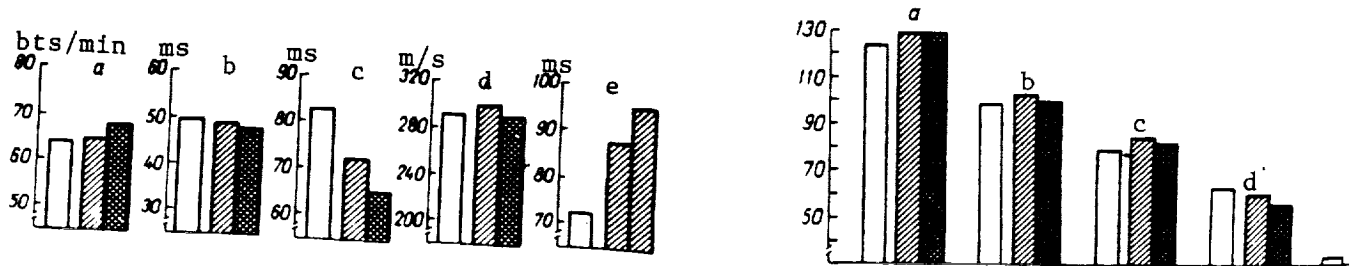


Figure 1: Changes in mean values of heart rate (a) phase of isometric contraction (b) and relaxation (c) ejection period (d) and phase of rapid filling (e) in a group of cosmonauts at rest during long-term (65-237 day) flights on Salyut-7-Soyuz-T  
Here and in Figures 2-4 white bars - preflight; hatched bars - 1 month of flight, cross-hatched bars - 2-8 months in flight

Figure 2: Change in mean values of end-systolic (a), true systolic (b), mean dynamic (c), diastolic (d), and pulse (e) blood pressure (in mm Hg) in a group of cosmonauts at rest during long-term (65-237 day) flights on Salyut-7-Soyuz-T

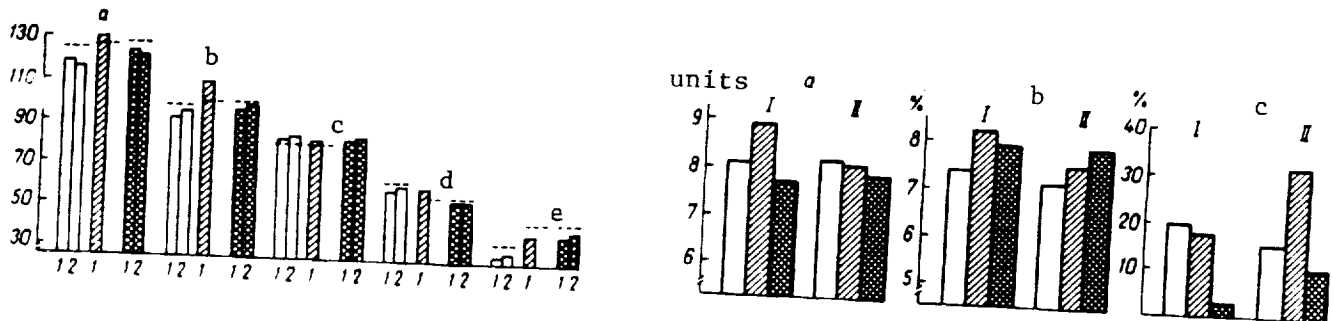


Figure 3: Change in mean values of end-systolic (a), true systolic (b), mean dynamic (c), diastolic (d), and pulse (e) blood pressure (in mm Hg) in a group of cosmonauts pre-exposed to LBNP during long-term (65-237 day) flights on Salyut-7-Soyuz-T  
 1 - decompression of 35 mm Hg, 2 - decompression of 45 mm Hg. Broken line - parameter before the test.

Figure 4: Change in mean values of redistribution of pulsed blood filling (a), tonus of large (b) and precapillary (c) vessels of the head (basin of the internal carotid artery) at rest during long-term (65-237 day) flights on Salyut-7-Soyuz-T  
 I - right hemisphere, II - left hemisphere

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ABSTRACT = This is the twenty-fifth issue of NASA's Space Life Sciences Digest. It contains abstracts of 42 journal papers or book chapters published in Russian and of 3 Soviet monographs. Selected abstracts are illustrated with figures and tables from the original. The abstracts in this issue have been identified as relevant to 26 areas of space biology and medicine. These areas include: adaptation, body fluids, botany, cardiovascular and respiratory systems, developmental biology, endocrinology, enzymology, equipment and instrumentation, exobiology, gravitational biology, habitability and environmental



effects, human performance, immunology, life support systems, man-machine systems, mathematical modeling, metabolism, microbiology, musculoskeletal system, neurophysiology, nutrition, operational medicine, psychology, radiobiology, reproductive system, and space biology and medicine.

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